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ABSTRACT

This technical specialty course is one of thirty-five courses designed for use by two-year postsecondary institutions in five nuclear technician curriculum areas: (1) radiation protection technician, (2) nuclear instrumentation and control technician, (3) nuclear materials processing technician, (4) nuclear quality-assurance/quality-control technician, and (5) nuclear reactor (plant) operator trainee. This course, Civil/Structural Inspection, contains six modules: Inspection of Construction Operations; Structural Steel Materials, Installation, and Inspection; Concrete Materials; Concrete Preparation, Production, Placement, and Finishing; Concrete Testing and Inspection; and Prestressed Concrete Materials, Fabrication, and Inspection. Each module follows a typical format including the following sections: introduction, module prerequisites, objectives, subject matter, exercises, materials, procedures, data tables, reference materials, and tests. (A master index and suggested program planning guides are also available--see CE 026 856 and CE 026 639-643.) (LRA)

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ED192111

Nuclear Technology Series

COURSE 29
CIVIL / STRUCTURAL INSPECTION

CENTER FOR OCCUPATIONAL RESEARCH
AND DEVELOPMENT, INC.

4800 LAKEWOOD DRIVE
WACO, TEXAS 76710

CE 026 669

U S DEPARTMENT OF HEALTH,
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PREFACE

ABOUT NUCLEAR TECHNOLOGY MODULES

The modules – developed for use in two-year postsecondary technical institutions to prepare technicians for employment – are useful in industry for updating employees in company-sponsored training, and as laboratory texts in engineering schools. The principles, techniques and skills taught in the modules, based on tasks that nuclear technicians perform, were obtained from a nationwide advisory committee of employers of nuclear technicians. Each module was written by a working technical expert/experienced writer team and tested with students.

A module contains the following elements:

Introduction, which identifies the topic and often includes a rationale for studying the material.
Module Prerequisites, which identify the material a student should be familiar with before studying the module.
Objectives, which clearly identify what the student is expected to know for satisfactory module completion. The objectives, stated in terms of action-oriented behaviors, include such action words as operate, measure, calculate, identify and define, rather than words with many interpretations, such as know, understand, learn and appreciate.
Subject Matter, which presents the background theory and techniques supportive to the objectives of the module. Subject matter is written with the technical student in mind.
Exercises, which provide practical problems to which the student can apply this new knowledge.
Materials, which identify the equipment required to complete the laboratory procedure.
Procedures, which is the experiment section, or "hands-on" portion of the module (including step-by-step instruction) designed to reinforce student learning.
Data Tables, which are included in most modules for the first year (or basic) courses to help the student learn how to collect and organize data.
Reference Materials, which are included as suggestions for supplementary reading/viewing for the student.
Test, which measures the student's achievement of the prestated objectives.

A helpful Index has been added at the end of each course.

The materials contained herein were developed pursuant to a contract with the Office of Education, U.S. Department of Health, Education and Welfare: Contract No. 300780582. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

The Nuclear Technology Series consists of five curricula:

- Nuclear Reactor (Plant) Operator Trainee.
- Radiation Protection Technician.
- Nuclear Materials Processing Technician.
- Nuclear Quality-Assurance/Quality-Control Technician.
- Nuclear Instrumentation and Control Technician.

The completed Nuclear Technology Series consists of the following 35 technical specialty courses:

- Radiation Physics.
- Radiation Protection I.
- Principles of Process Instrumentation.
- Heat Transfer and Fluid Flow.
- Introduction to Nuclear Systems.
- Instrumentation and Control of Reactors and Plant Systems.
- Reactor Operations.
- Reactor Safety.
- Reactor Auxiliary Systems.
- Power Plant Systems.
- Radiation Detection and Measurement.
- Reactor Physics.
- Power Plant Chemistry.
- Introduction to Quality Assurance/Quality Control.
- Metallurgy and Metals Properties.
- Mechanical Component Characteristics and Specifications.
- Radiation Protection II.
- Radiological Emergencies.
- Radiation Shielding.
- Radiation Monitoring Techniques (Radiochemical).
- Radioactive Materials Disposal and Management.
- Advanced Radionuclide Analysis.
- Nuclear Chemical Processes.
- Nuclear Systems and Safety.
- Radioactive Material Handling Techniques.
- Nondestructive Examination (NDE) Techniques I.
- Metrology.
- Welding Inspection.
- Civil/Structural Inspection.
- Mechanical Inspection.
- Quality-Assurance Practices.
- Nondestructive Examination (NDE) Techniques II.
- Control Systems I.
- Control Systems II.
- Power Plant Electrical Systems and Components.

Availability: Instructional modules are available individually or by courses from:

Center for Occupational Research and Development
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Telephone (817) 772-8756

Printed:

NUCLEAR TECHNOLOGY

MODULE 29-1

INSPECTION OF CONSTRUCTION OPERATIONS

COURSE 29 CIVIL/STRUCTURAL INSPECTION

CORD

CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

4800 LAKEWOOD DRIVE WACO, TEXAS

COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

MODULE 29-1	Inspection of Construction Operations
MODULE 29-2	Structural Steel Materials, Installation and Inspection
MODULE 29-3	Concrete Materials
MODULE 29-4	Concrete Preparation, Production, Placement and Finishing
MODULE 29-5	Concrete Testing and Inspection
MODULE 29-6	Prestressed Concrete Materials, Fabrication and Inspection

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INTRODUCTION

The construction of a nuclear power plant is typically a project of 8-10 years duration, involving a full range of engineering and construction activities.

Field work begins with site work, and proceeds with excavation, dewatering, concrete work, and fill.

This module describes these activities, the equipment and materials used, and some of the inspection operations which may be performed by the QA/QC technician.

Structural steel erection work usually follows these activities, and is presented in the next Module, 29-2.

MODULE PREREQUISITES

None.

OBJECTIVES

Upon completion of this module, the student/trainee should be able to:

1. Given a description of a hypothetical nuclear power plant site, and a list of site preparation and early construction activities, organize the activities in the proper chronological order.
2. Given a typical concrete design mix and general concrete batcher tolerance limits, calculate allowable variations in batching water, cement and aggregates.

3. Given sketches of typical concrete form set-ups, label correctly the indicated component parts. To further demonstrate a knowledge of form work, answer written questions on: (1) slip forms, (2) column forms, (3) panel forms, and (4) form erection.
4. Demonstrate a knowledge of reinforcing steel installation practices by answering written questions on: (1) coverage, (2) reinforcement theory, (3) re-bar supports, and (4) re-bar location and tying practices.
5. Demonstrate a knowledge of concrete production, placement and curing operations by:
    a. calculating batching time and component material usage for a given batch plant operation and a given design mix.
    b. listing factors that should be observed during placement operations which affect concrete strength, and
    c. describing the concrete curing process.
6. Demonstrate a knowledge of form removal and surface finishing practices by answering written questions on: (1) time of removal, (2) surface repairs, and (3) characteristics of surface defects.
7. Demonstrate a knowledge of structural fill and soils testing practices by answering written questions on: (1) classes of soils, (2) soil density, (3) fill material characteristics, (4) placing and compacting procedures, (5) moisture content testing, and (6) % density tests: rubber ballon test, and sand cone test.

SITE PREPARATIONS AND EXCAVATION

Before any construction operations begin, field sites are surveyed to accurately locate boundaries and topographic features. The area to be cleared is then identified and marked, usually with stakes, in agreement with the plans and specifications. The inspector, or QA/QC technician, may be required to verify that the clearing limits have been established correctly.

A safety program must be established as mobilization begins. Any potential hazards must be identified, and arrangements made for fire protection, first aid, ambulance service, and hospitalization.

The removal of trees, bushes and other foliage is known as clearing and grubbing. In wooded areas, the first stage of clearing is swamping, which includes the initial removal of underbrush and small undergrowth which could interfere with felling of larger timber. Grubbing is the removal of stumps and roots. Timber is usually cut up with chain saws and hauled from the site, and the remaining organic materials bulldozed into piles for disposal by burning. Disposal operations must follow appropriate air pollution regulations, however. Burning permits must be obtained, and burning should not be permitted in periods of high wind. Debris must be prevented from being carried into waterways, streams or reservoirs. Clearing activities should be monitored by an inspector to assure compliance with the site plans, and applicable codes and regulations.

Following site clearing operations, access roads to the site and parking lots for construction personnel are laid out and constructed. It is not uncommon to have up to 3,000 workers on a single-unit power plant site at peak times of the construction work.

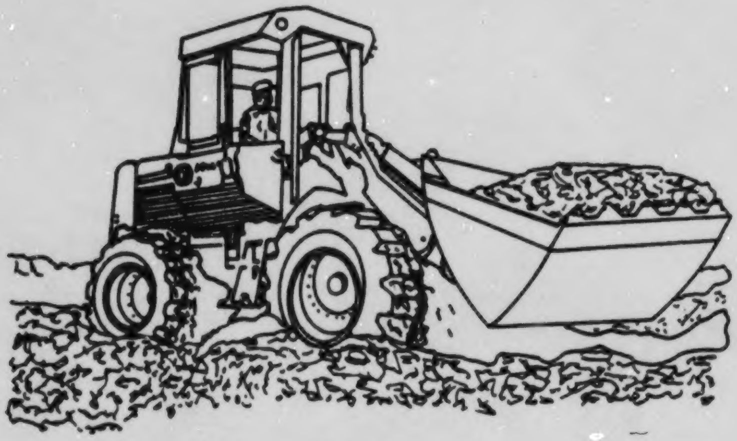
Buildings, either permanent or temporary, are then constructed for offices; personnel change facilities; shops for various crafts, such as carpenters, fitters, electricians and welders; warehouses; and sanitary facilities. Utilities are brought in and connected, and general mobilization begins.

Inasmuch as many of the heavy equipment items such as transformers, heat exchangers, and large pumps and motors are normally shipped by rail, railroad siding or spur facilities are usually constructed on plant sites. In remote areas, cement and concrete aggregate materials may also be shipped in by rail, and the rail facilities would thus be needed in the early phases of the site work.

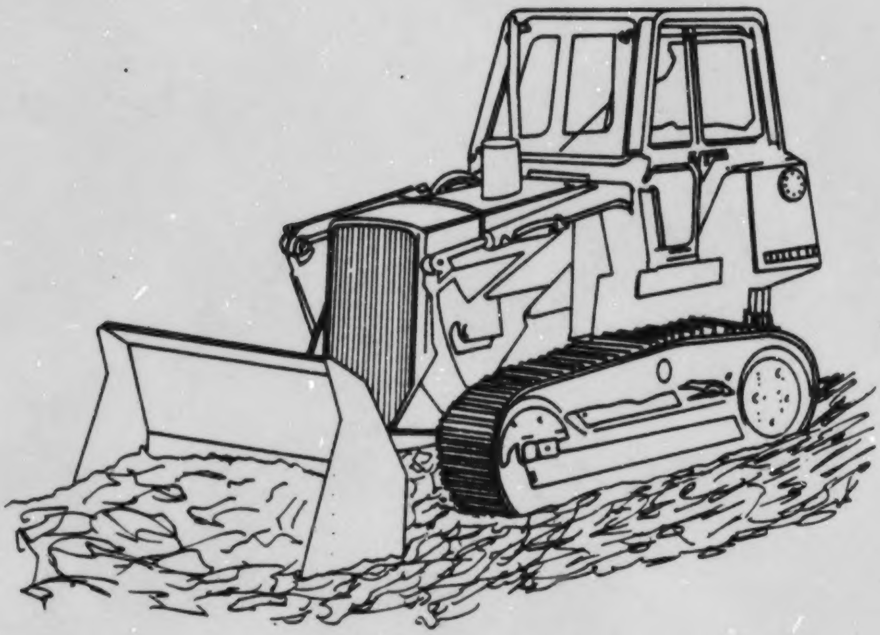
Excavation and grading work begins when the site clearing is completed. The first stage of this work is the stripping of top soil. Top soil is usually stockpiled for later use in final grading in areas that will be seeded and landscaped.

Excavation is performed with a variety of heavy equipment, including bulldozers, front-end loaders, excavators, earth movers and dump trucks. Rock formations that must be removed are drilled, loaded with explosives such as TNT and blasted. The broken material is then shoveled easily and hauled from the excavated area. Figures 29-1-1 through 29-1-3 illustrate some of the types of equipment used for excavation.

QA/QC technicians are frequently used to monitor or inspect excavation work for conformance to such drawing requirements as location, elevation, slope, and the removal of loose materials.

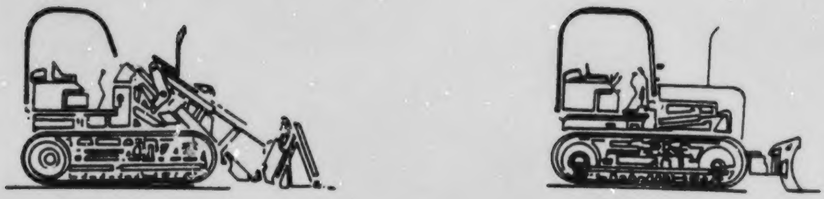


4-Wheel Drive Loader

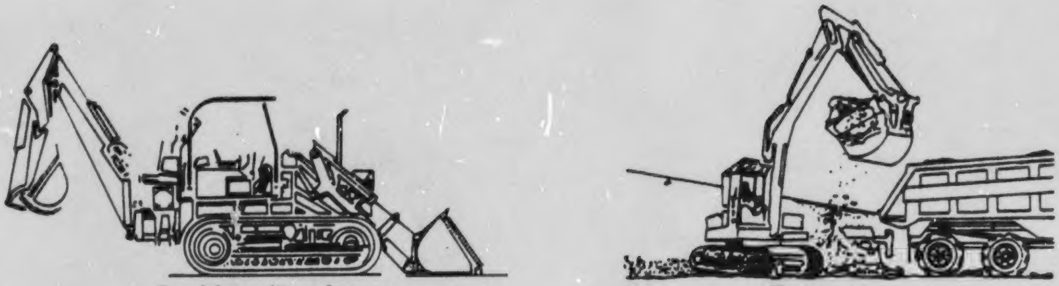


Crawler Loader

Figure 29-1-1 Construction Equipment



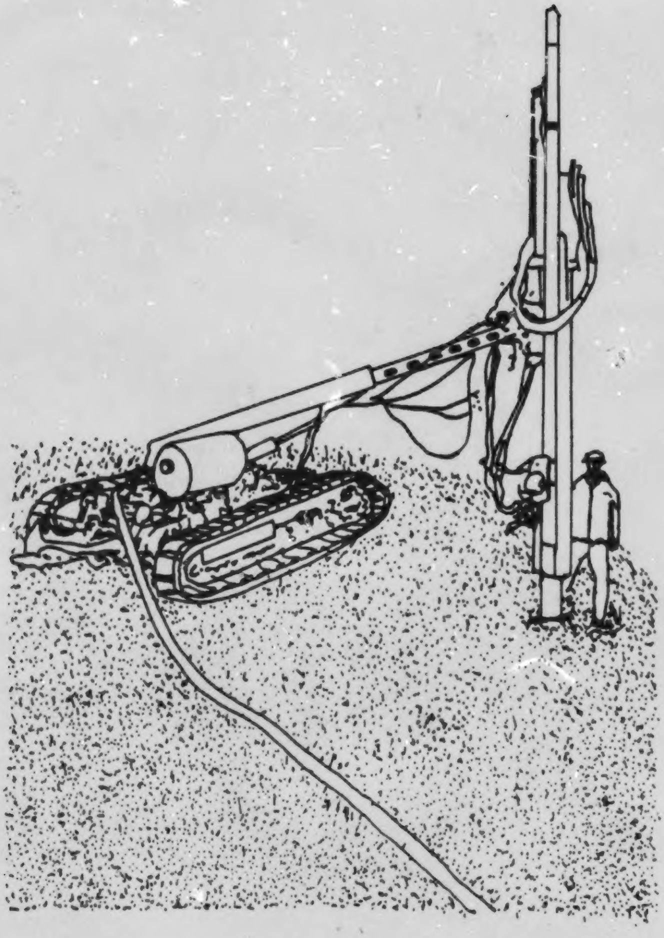
Loader   Bulldozer



Backhoe/Loader   Excavator

Types of Crawlers

Figure 29-1-2 Construction Equipment



Pneumatic Crawler Drill

Figure 29-1-3 Construction Equipment

SITE DE-WATERING AND DRAINAGE

During excavation and other construction operations, including concrete placement and backfilling, the work site must be kept dry. On most large construction projects, the excavation site is rather deep and below the groundwater line. Special dewatering equipment and procedures are needed to maintain the area in the required condition.

One dewatering method is a combined pumping and piping system. The piping is made up of pumping points driven several feet below the dry level required, and then connecting the pumping points with headers connected to heavy duty pumps.

Another method of dewatering is direct pumping from sumps which are either open, or are made from pipe or gravel pockets.

Figure 29-1-4 shows a dewatering pumping ring system installed around a deep excavation.

The duties of site QA/QC technicians may include monitoring the effectiveness of the dewatering systems.

CONCRETE MATERIALS AND BATCHING EQUIPMENT

Concrete is a mixture of cement, aggregates, water and additives (called admixtures) which is plastic and workable when mixed, and which "sets" or hardens a few hours after mixing. Concrete is basic building material for nearly all construction projects, and is used for foundations, walls, floor slabs, roof slabs, columns, beams and storage vessels or containments.

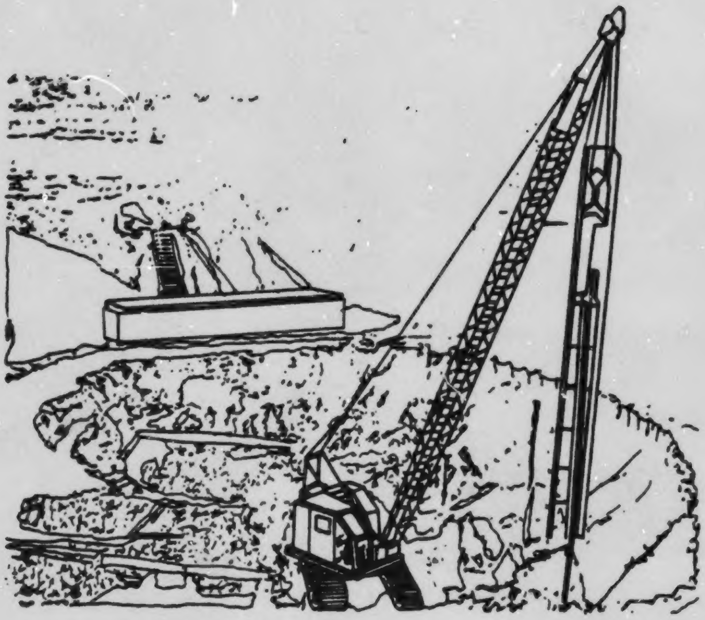


Figure 29-1-4 Dewatering Pumping Ring System

Concrete is strong in compression and relatively weak in tension, and derives its strength from the cement which binds the aggregate particles together. The strength of the hardened concrete is affected by the quality and proportions of all the component materials. Of critical importance is the amount of water used, which is expressed as the water-cement ratio.

Detailed information on the component materials is presented in Module 29-3, Concrete Materials.

To maintain the product of consistent, high quality concrete with minimal variations between batches, the materials must be measured accurately and mixed properly.

Concrete may be mixed in two principal ways for construction use - central mixed or truck mixed (also called transit mixed). In the first, the concrete is mixed in a stationary mixer at the batch plant and delivered to the work site in a truck mixer or agitator or other transportation device. In the second, the concrete is mixed in a truck mixer - generally in transit to the job but frequently after the job is reached. Each of the types of mixing operations has its own special problems of control. The facilities for the control of the quality of the ingredients and of the accuracy of the measuring of the dry materials are the same for the central mixing and truck mixing operations. The central mixing plant provides for better control of mixing water and consistency than does the truck mixing operation, a critical factor in the resultant concrete quality. The truck mixing operation, however, provides the opportunity to better control the time between the introduction of mixing water and the discharge of the concrete at the job location.

Concrete component materials are loaded and weighed in suitable containers called batchers. (Thus the expression, "batch plants".) Cement materials are not loaded and weighed in the same batcher used for aggregate materials. Each batcher is normally equipped with a scale and also with the necessary mechanisms for its operation. The charging device for each batcher must be capable of stopping the flow of materials within specified tolerances. Typical batcher tolerances are as follows:

- Cement Batcher - ±1% of the required weight of material being weighed, or ± 0.3% of scale capacity, whichever is greater.
- Aggregates 1½" or smaller - ±2% of the required weight of material being weighed, or ± 0.3% of scale capacity, whichever is greater.
- Aggregates larger than 1½" - ±3% of the required weight of material being weighed, or ± 0.3% of scale capacity, whichever is greater.
- Water - ±1% of the required weight of material being weighed, or ± 0.3% of scale capacity, whichever is greater.
- Admixtures - ±3% of the required weight of material being weighed, or ±0.3% of scale capacity, or ± the minimum dosage rate for one sack of cement, whichever is greater.

Batchers range from manual through all stages to complete automation. All are capable of providing satisfactory accuracy.

A manual batcher is equipped with gates or valves which are opened and closed manually, with the accuracy of the weighing operation being dependent upon the operator's visual observation of the scale. The gates or valves may be operated by hand, or by pneumatic, hydraulic, or electrical power assists. A semi-automatic batcher is one equipped with gates or valves which are separately opened manually to allow the material to be weighed, but which are closed automatically when the designated weight of each material has been reached.

An automatic batcher is one equipped with gates or valves which, when actuated by a single starter switch, will open automatically at the start of the weighing operation of each material, and close automatically when the designated weight of each material has been reached.

Batching equipment is usually arranged to permit "ribbon" loading - that is, the simultaneous loading of the cement and aggregates. In central-mixing operations, the water is also added with the other materials, but in truck-mixing operations, the water is added later.

Detailed information on concrete batching and mixing is presented in Module 29-4, Concrete Preparation, Production, Placement and Finishing.

The QA/QC technician, in the capacity of an inspector, may be required to inspect all phases of the concrete batching operations, including witnessing the calibration of cement scales, aggregate scales, water meters and admixture meters.

CONCRETE FORMS

"Form work" is the term employed to include the total system of support for freshly placed concrete - form sheathing plus all supporting members, hardware, and bracing.

The quality of cast-in-place concrete, relative to size, shape and alignment of slabs, beams, walls and other concrete structural elements, depends on accurate construction and setting of the forms.

Forms must be:

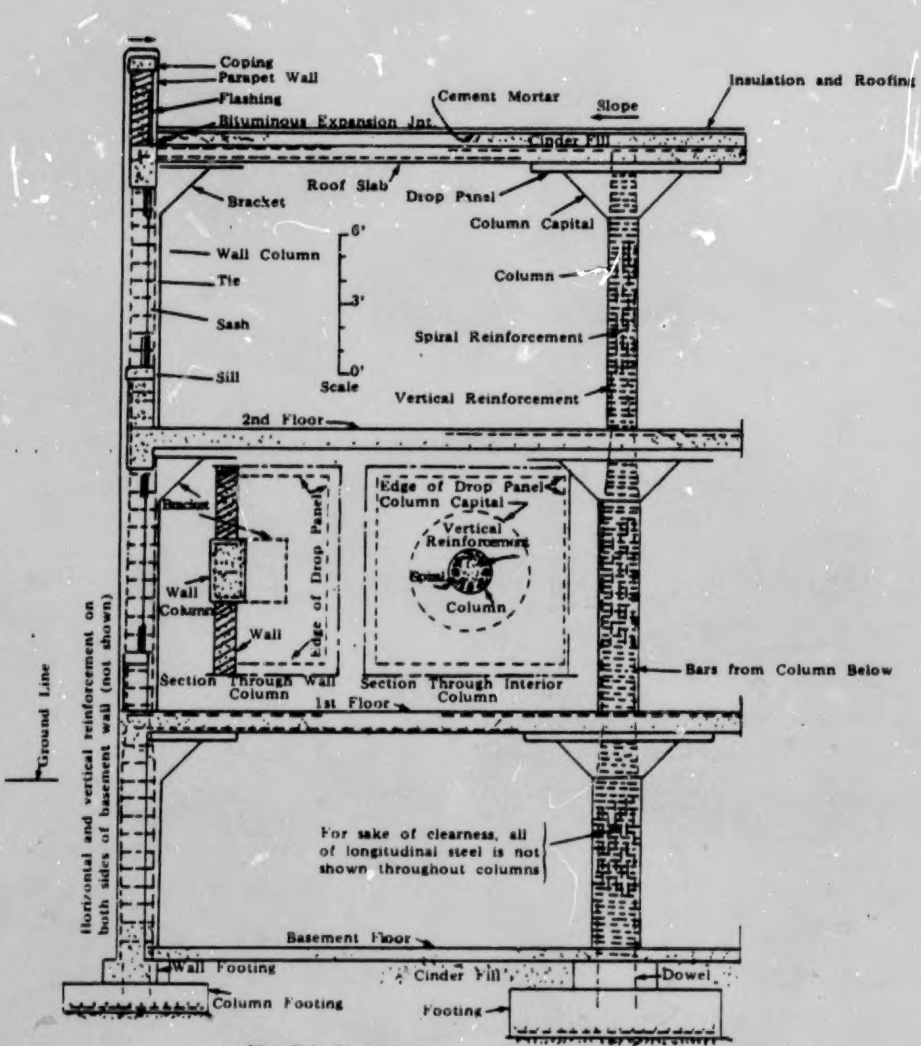
- built to correct dimensions.
- sufficiently rigid under the construction loads to maintain the desired shape.
- stable and strong enough to maintain alignment.
- substantially constructed to withstand handling and reuse without losing dimensional integrity.
- economical to construct and use.

Forms are most commonly constructed of wood. Wood is easily worked and has the unique characteristic of the capacity to absorb large overloads for short periods.

Figure 29-1-5 illustrates typical building construction using reinforced concrete for footings, walls, columns, and slabs.

The principal construction requirements for footings are sound concrete and correct position to align with walls and columns. Appearance of footings is usually unimportant because they are below grade. Sometimes fabricated forms are omitted completely and the concrete is cast directly against the excavation. Since footings are generally shallow, lateral pressure from the fresh concrete is relatively small and the required bracing is simple. Figure 29-1-6 shows a typical form arrangement for a wall footing.

The forms for simple, rectangular column footings are bottomless boxes. They are constructed with two end sections and two sides and equipped with ties to prevent the sides of the box from bulging under concrete pressure. A template for positioning dowels may be attached to the top of the form box. Two types of column footing forms are shown in Figure 29-1-7, one with external ties and the other with internal ties.


Coping
Parapet Wall
Flashing
Bituminous Expansion Jnt.
Cement Mortar
Slope
Insulation and Roofing
Cinder Fill
Roof Slab
Drop Panel
Bracket
Column Capital
6'
3'
0'
Scale
Wall Column
Tie
Sash
Sill
Column
Spiral Reinforcement
Vertical Reinforcement
2nd Floor
Bracket
Wall Column
Wall
Edge of Drop Panel
Section Through Wall Column
Edge of Drop Panel
Column Capital
Vertical Reinforcement
Spiral
Column
Section Through Interior Column
Bars from Column Below
1st Floor
Ground Line
Horizontal and vertical reinforcement on both sides of basement wall (not shown)
For sake of clearness, all of longitudinal steel is not shown throughout columns
Basement Floor
Wall Footing
Cinder Fill
Dowel
Column Footing
Footing

Flat Slab Construction

Figure 29-1-5 Typical Reinforced Concrete Building Construction

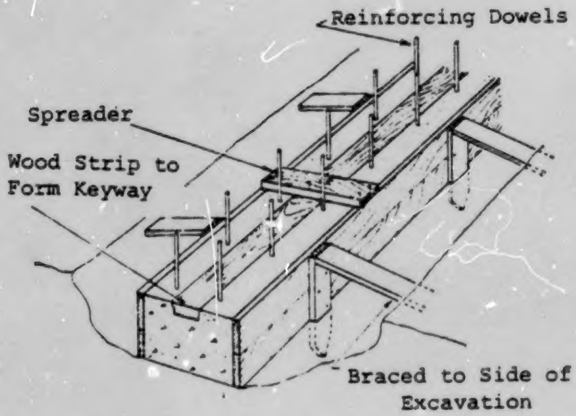

Reinforcing Dowels
Spreader
Wood Strip to Form Keyway
Braced to Side of Excavation

Figure 29-1-6 Typical Wall Footing Form

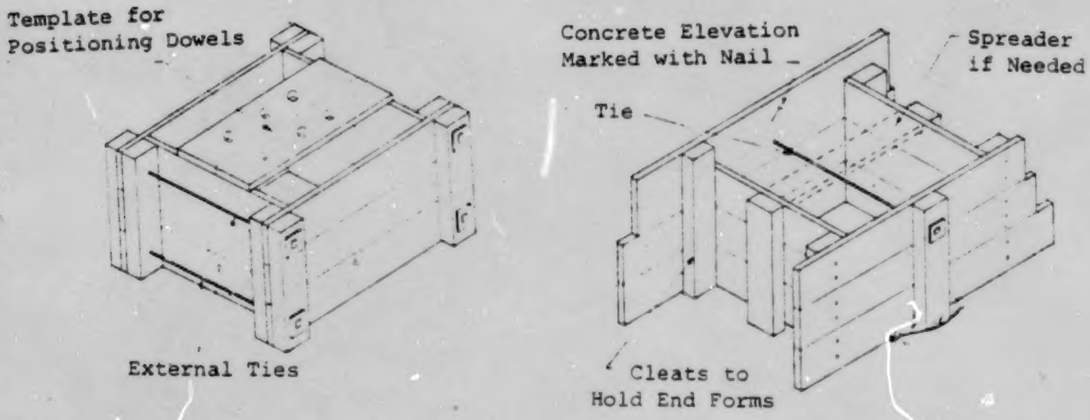

Template for Positioning Dowels
External Ties
Concrete Elevation Marked with Nail
Spreader if Needed
Tie
Cleats to Hold End Forms

Figure 29-1-7 Typical Column Footing Forms

The first step in constructing a wall form is to attach a sill or plate to the footing as a base for studs. Special care must be taken to align this strip, as it will determine the line of the wall. Studs are then erected, attached to the sill and held vertical by temporary braces. Sheathing material, of either boards or plywood panels, is then attached to the studs with nails. When the first wall form face is completed, the second is fabricated and set in place. Holes are drilled through both faces at the proper locations, and the wales are installed with ties. Permanent bracing is installed after the wales are in place or as the form is plumbed. Figure 29-1-8 shows the components of a typical wall form, set on a cast footing.

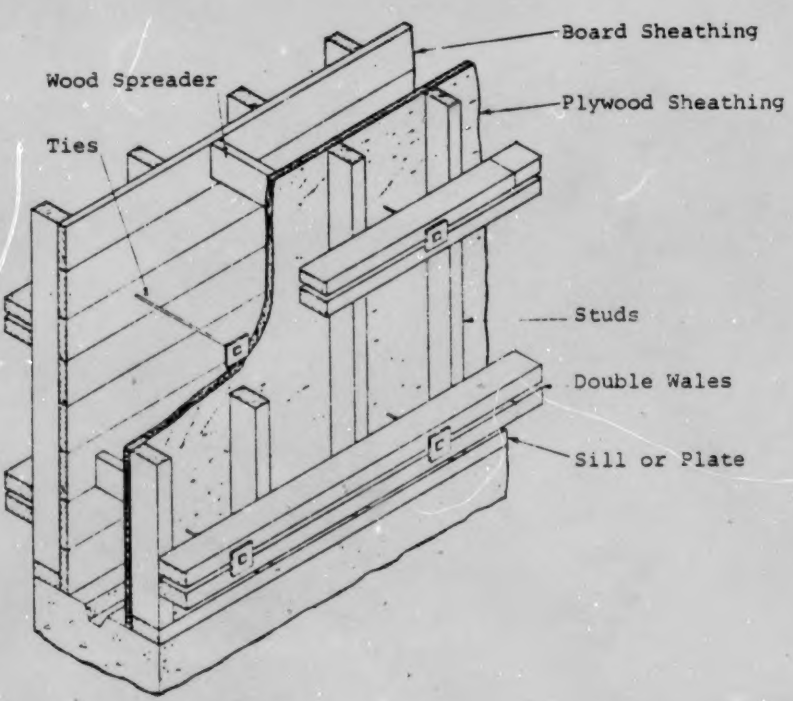
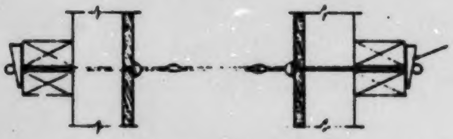

Board Sheathing
Wood Spreader
Plywood Sheathing
Ties
Studs
Double Wales
Sill or Plate

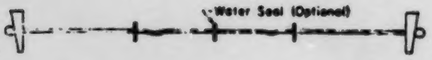
Figure 29-1-8 Typical Wall Form Components

Concrete form ties are tensile units designed to hold concrete forms secure against the lateral pressure of unhardened concrete. The two basic types of ties used are the continuous single member and the internal disconnecting types.

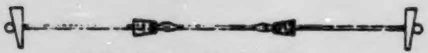
The continuous single member tie grips the exterior of the form, and is usually one of the types shown in Figure 29-1-9.



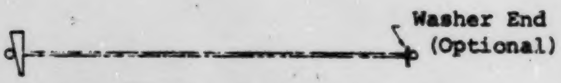
Snap Tie with Small Cone Spreader



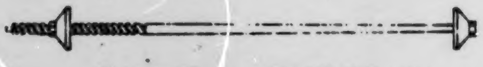
Washer Spreader, Crimped for Break Back



Wood Cone Spreader



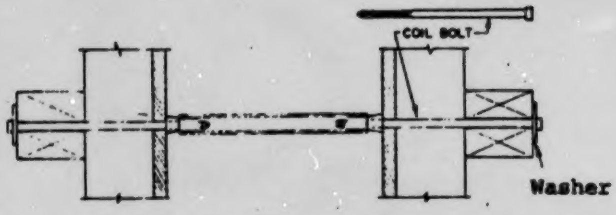
No Spreader; May be Pulled or May be Equipped with Break Points



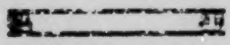
Taper Tie to be Withdrawn

Figure 29-1-9 Continuous Single Member Ties

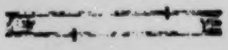
The internal disconnecting tie has an inner part with threaded connections to removable external members. The internal member usually remains in the concrete. Examples of these ties are shown in Figure 29-1-10.


COIL BOLT
Washer

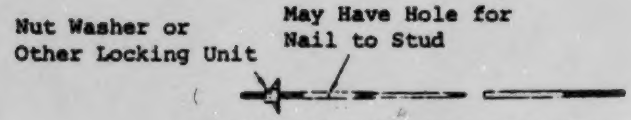
Coil Type Tie With Cone Spreader



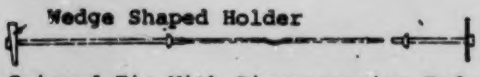
Plain Coil Type
(Also Available with 4 Struts)



Water Seal Coil Type


Nut Washer or
Other Locking Unit
May Have Hole for
Nail to Stud

Plain Tie With She-Bolt Disconnecting Ends


Wedge Shaped Holder

Crimped Tie With Disconnecting Ends

Figure 29-1-10 Internal Disconnecting Ties

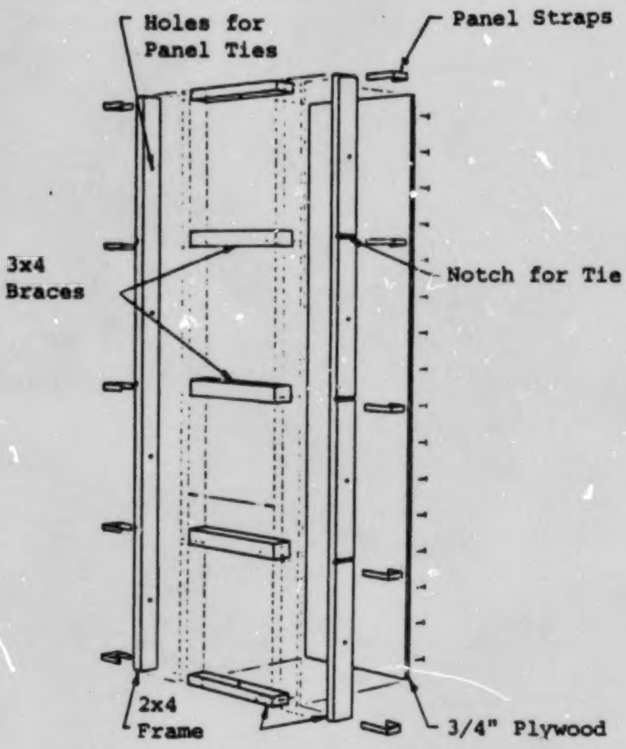
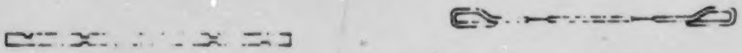

Holes for Panel Ties
Panel Straps
3x4 Braces
Notch for Tie
2x4 Frame
3/4" Plywood

Figure 29-1-11 Pre-Fabricated Panel Form

Many contractor-built or ready-made prefabricated panel forms are also used for large project wall construction. Preassembled panels are set into position, tied together, and supported and braced as other types of wall forms. Figure 29-1-11 shows a typical contractor-built panel form. Figure 29-1-12 shows typical ties which are used on the prefabricated panels.


Strap Tie

Loop End Tie

Figure 29-1-12 Typical Panel Form Ties

Column forms require tight joints and extra care in anchoring the bases in position, due to the high lateral pressures imposed by the concrete during placement operations. Column bases may be formed as shown in Figure 29-1-13. Column forms may be constructed as shown in Figure 29-1-14 or Figure 29-1-15. Tall columns frequently have windows or openings at midheight or other intervals to make placing and consolidating the concrete easier. Clean-out openings as shown in Figure 29-1-15 are usually constructed at the column base for removal of waste or debris before concreting begins.

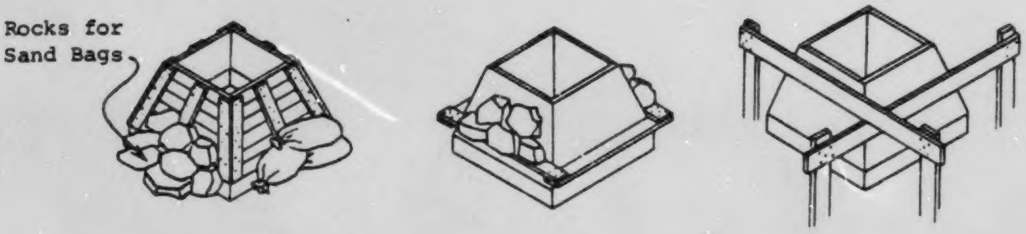


Figure 29-1-13 Column Base Forms

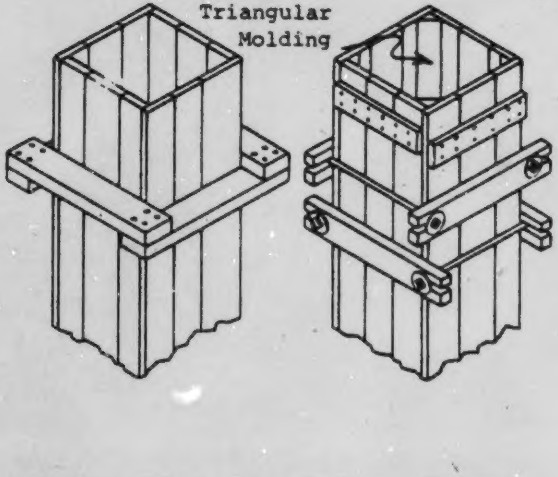


Figure 29-1-14 Column Forms

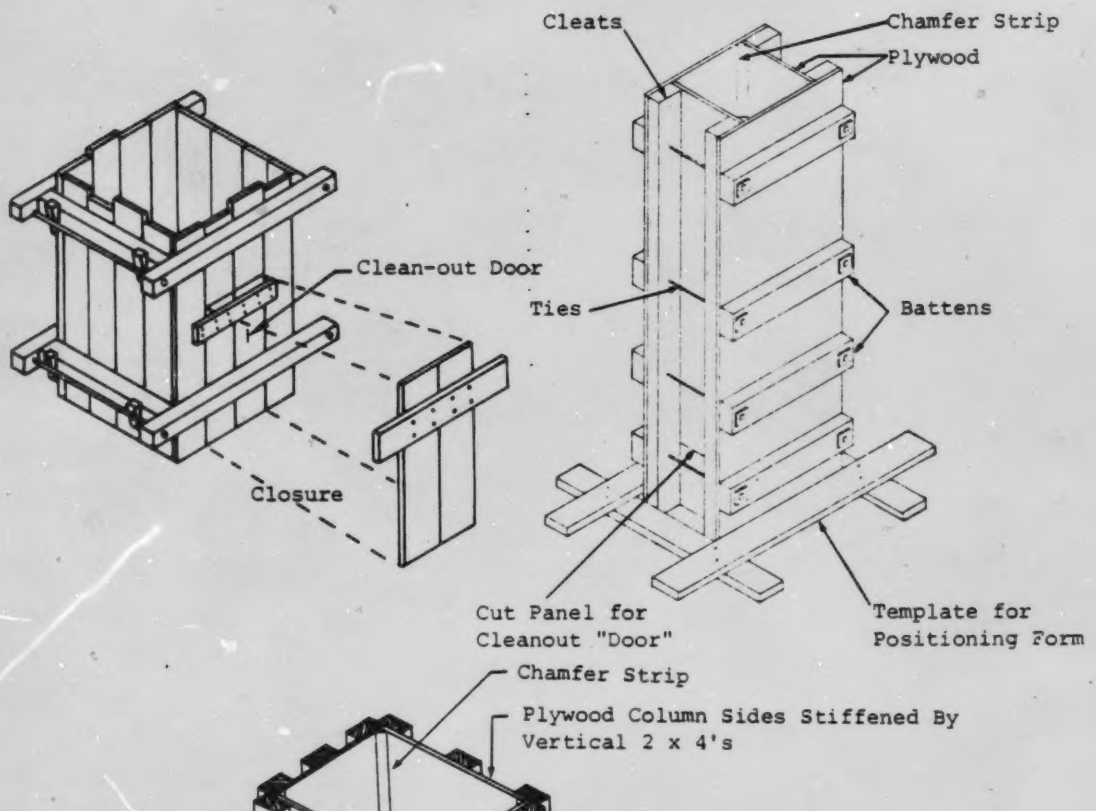

Clean-out Door
Closure
Cleats
Chamfer Strip
Plywood
Ties
Battens
Cut Panel for
Cleanout "Door"
Template for
Positioning Form
Chamfer Strip
Plywood Column Sides Stiffened By
Vertical 2 x 4's
Adjustable Column Clamps
Cleanout Door
Template for Positioning Form
Cleanout Closure Detail

Figure 29-1-15 Column Forms Showing Clean-out Doors

Beam and grinder form work consists of a beam bottom and two ties, plus the necessary ties, shoring and braces. Section views of typical beam forms are shown in Figure 29-1-16.

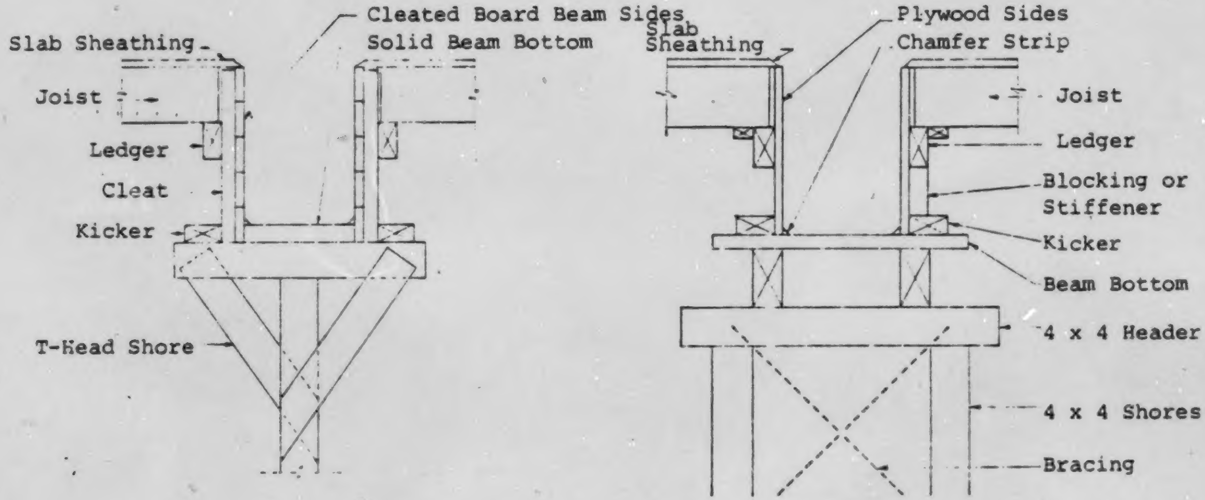

Cleated Board Beam Sides
Solid Beam Bottom
Slab Sheathing
Joist
Ledger
Cleat
Kicker
T-Head Shore
Slab Sheathing
Plywood Sides
Chamfer Strip
Joist
Ledger
Blocking or Stiffener
Kicker
Beam Bottom
4 x 4 Header
4 x 4 Shores
Bracing

Figure 29-1-16 Typical Beam Forms

Slab forms consist simply of sheathing panels supported by joists and braces, as shown in Figure 29-1-17. They may be supported by beams, such as those cast in the forms shown in Figure 29-1-16. Slabs may be cast monolithically (in a single mass) with a beam, as shown in Figure 29-1-18.

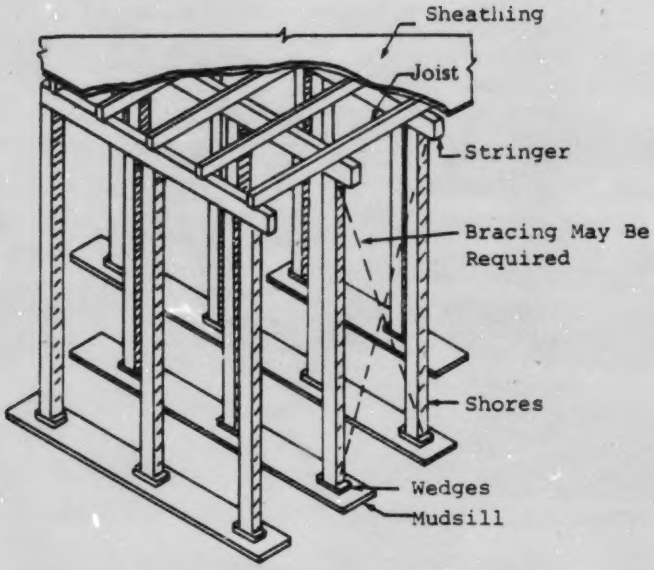

Sheathing
Joist
Stringer
Bracing May Be Required
Shores
Wedges
Mudsill

Figure 29-1-17 Flat Slab Form

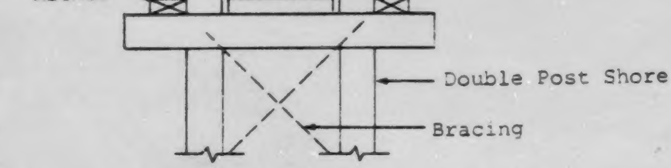

Concrete
Slab Sheathing
Ledger
Stiffener
Kicker
Beam Side
Beam Bottom
Double Post Shore
Bracing

Figure 29-1-18 Slab and Beam Construction, Monolithic Pour

Curved forms are also used frequently on power plant projects. Large radius curves can easily be formed with standard prefabricated panels, or with plywood sheathing wrapped around blocking frames. Short radius curves are usually made with multi-layers of thin plywood supported on curved blocking members, as shown in Figure 19.

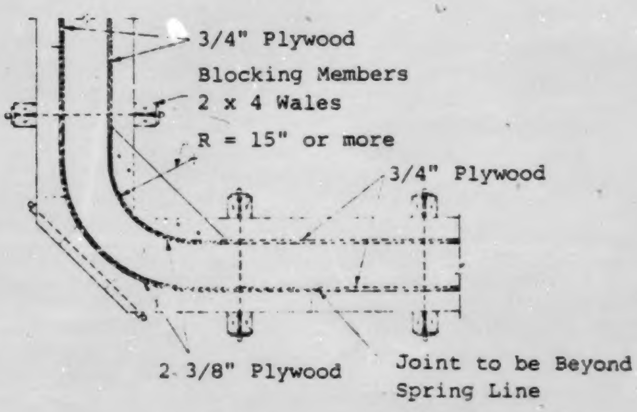


Figure 29-1-19 Small Radius Curved Form

A special type of form sometimes used is the slip form. This form is used on vertical structures such as chimneys, elevator shafts, and core structures for buildings. The form is jacked vertically on reinforced jacking bars or dowels embedded in the formed concrete. The rate of vertical rise of the forms and the concrete is timed to a balance between curing of the concrete, and development of sufficient strength to hold the forms, while not being so slow as to preclude proper bonding of the new concrete as it is placed on top of the prior material.

The quality of the finished concrete depends on good workmanship in constructing and setting the forms, including attention to the following points:

- proper splices of studs, wales or shores
- staggering of joints or splices in sheathing, plywood panels, and bracing.
- proper seating of shores.
- proper number and location of form ties or clamps.
- proper tightening of form ties or clamps.
- secure connection of shores to joints, stringers or wales to resist uplift or torsion at joints.
- proper coating of forms.

All of these points should be checked by the cognizant inspector or field supervisor before concrete is placed, or admitted to the forms. These duties may be assigned to a qualified QA/QC technician.

Supplemental information on the selection and usage of concrete forms is available from the American Concrete Institute (ACI).

INSTALLATION OF REINFORCING STEEL AND OTHER EMBEDMENTS

The term reinforcing steel is applied to the steel, usually deformed bars, which is used to reinforce concrete where forces exist (tension) which the concrete cannot withstand.

Tension in concrete can be caused by bending or shear as in beams, by drying shrinkage after concrete hardens, and by temperature changes. Figure 29-1-20 illustrates how a loaded member deflects and produces tension on the lower surface, sometimes producing tension cracks. Concrete is weak and brittle in tension, and without reinforcement,

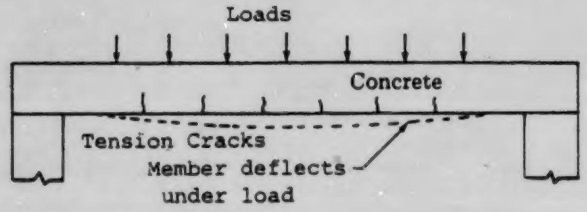


Figure 29-1-20 Deflection and Tension in Loaded Member

would fail suddenly without warning shortly after the first crack appeared.

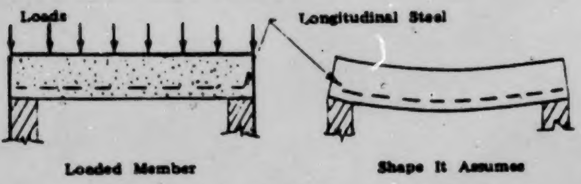
Reinforcing steel, then, is required in that part or area of a concrete structure which is in tension. Figure 29-1-21 shows five types of members and how reinforcing bars, or "re-bars", are located within, along with exaggerated illustrations of the shape each assumes under load.

It is important that bars be placed and held in position as shown on the placement drawings. The strength of any concrete member is greatly affected by improper positioning of the re-bars. For example, lowering the top bars or raising the bottom bars by ½" more than specified in a 6" thick slab could reduce its load carrying capacity by 20%.

Standard practice allows a tolerance of ±¼" in the positioning of bars above forms in the bottom of beams, joints and slabs.

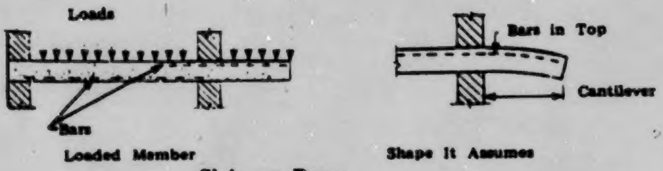
The proper embedment of bars in concrete is also important. The concrete cover protects the bars from fire hazards, corrosion and weather exposure. Unless otherwise specified, the minimum standard covers (outside of bar to face of concrete) illustrated in Figure 29-1-22 should be observed.

(1)


Loads
Longitudinal Steel
Loaded Member
Shape It Assumes

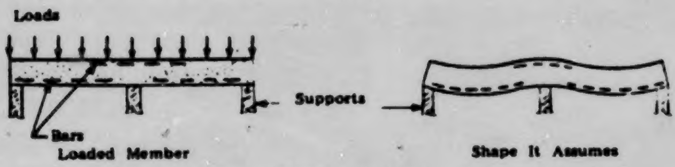
Slab or Beam

(2)


Loads
Bars
Bars in Top
Cantilever
Loaded Member
Shape It Assumes

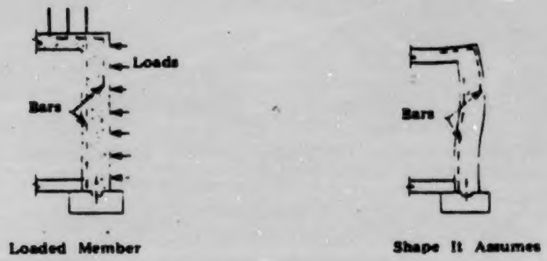
Slab or Beam

(3)


Loads
Bars
Supports
Loaded Member
Shape It Assumes

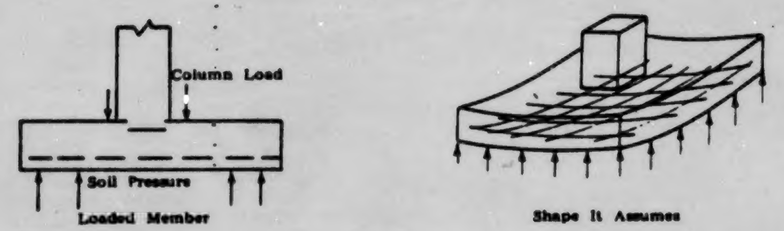
Slab or Beam

(4)


Loads
Bars
Bars
Loaded Member
Shape It Assumes

Wall

(5)


Column Load
Soil Pressure
Loaded Member
Shape It Assumes

Column Footing

Figure 29-1-21 Structural Concrete Shapes: Forces and Deflection

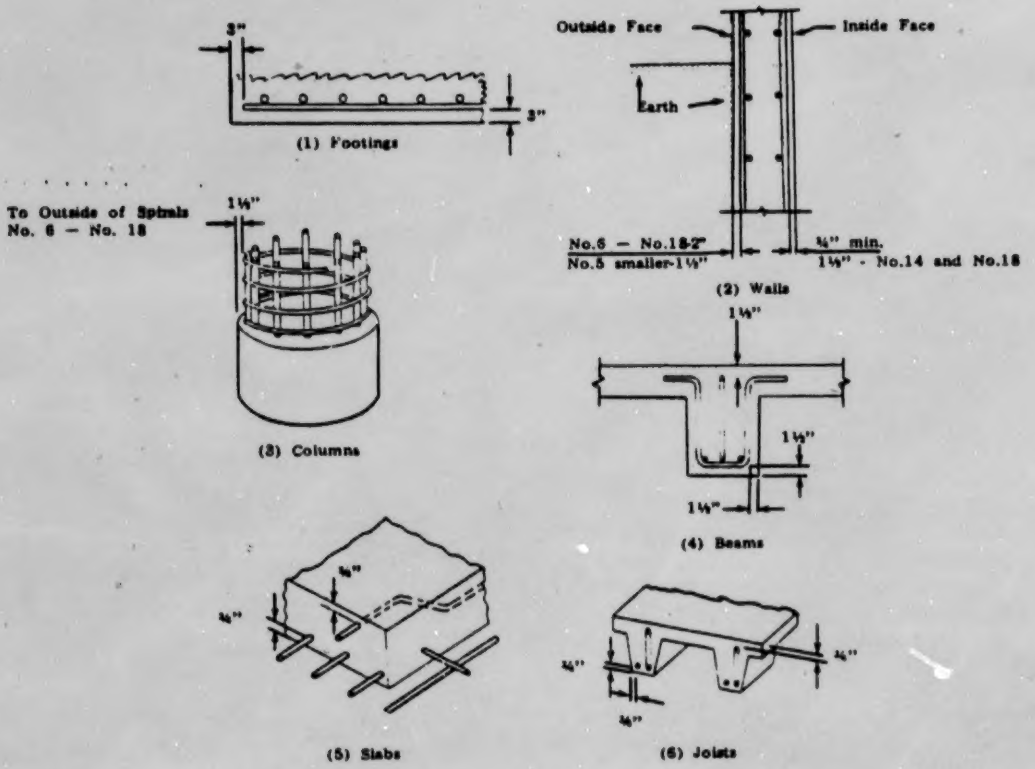

3"
3"
(1) Footings
Outside Face
Inside Face
Earth
No.6 — No.18-2"
No.5 smaller-1½"
¾" min.
1½" - No.14 and No.18
(2) Walls
To Outside of Spirals
No. 6 — No. 18
1½"
(3) Columns
1½"
1½"
1½"
(4) Beams
¾"
¾"
(5) Slabs
¾"
¾"
¾"
(6) Joists

Figure 29-1-22 Minimum Concrete Cover Over Reinforcing Steel

Bar supports are used to firmly hold bars at the required clearance from the forms before and during the placing of concrete. Bar supports may be formed from steel wire or rods, or concrete blocks. Standard types are sizes of wire supports are listed in Figure 29-1-23.

Pre-cast concrete blocks are available in three types and various sizes, as shown in Figure 29-1-24.

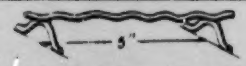
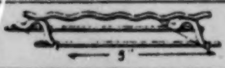
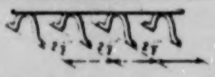
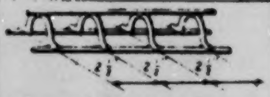
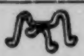
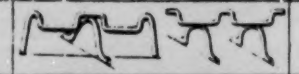
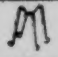
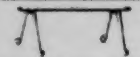
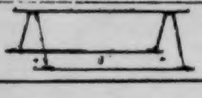
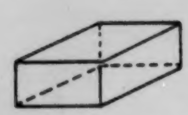
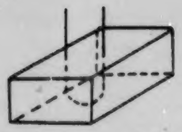
Symbol	Bar Support Illustration	Type of Support	Standard Sizes
SB		Slab Bolster	¾, 1, 1½, and 2 inch heights in 5 ft. and 10 ft. lengths
SBR		Slab Bolster with Runners	Same as SB
BB		Beam Bolster	1", 1½", 2"; over 2" to 5" heights in increments of ¼"; in lengths of 5 ft.
UBB		Upper Beam Bolster	Same as BB
BC		Individual Bar Chair	¾, 1, 1½, and 1¾" heights
JC		Joist Chair	4, 5, and 6 inch widths and ¾, 1, and 1½ inch heights
HC		Individual High Chair	2 to 15 inch heights in increments of ¼ in
CHC		Continuous High Chair	Same as HC in 5 and 10 foot lengths
UCHC		Upper Continuous High Chair	Same as CHC

Figure 29-1-23 Standard Types and Sizes of Wire Bar Supports



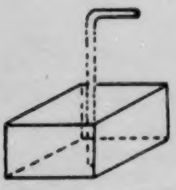
Size Range: 2" x 2" x ¾" thick, through 6" x 6" x 3" thick.

(1) Plain Precast Concrete Blocks



Size Range: 2" x 2" x ¾" thick, through 3" x 3" x 3" thick.

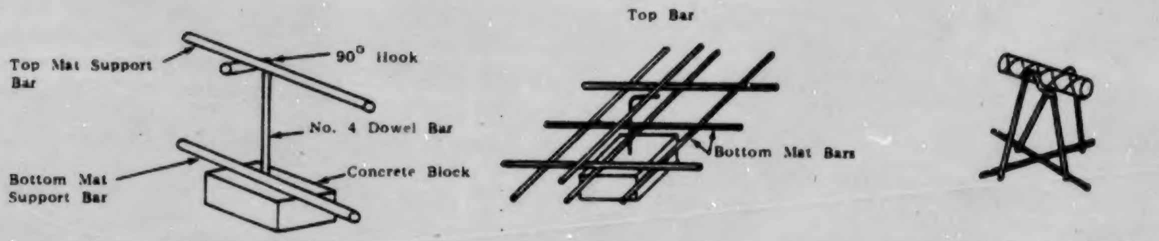
(2) Precast Concrete Blocks With Tie-Wires



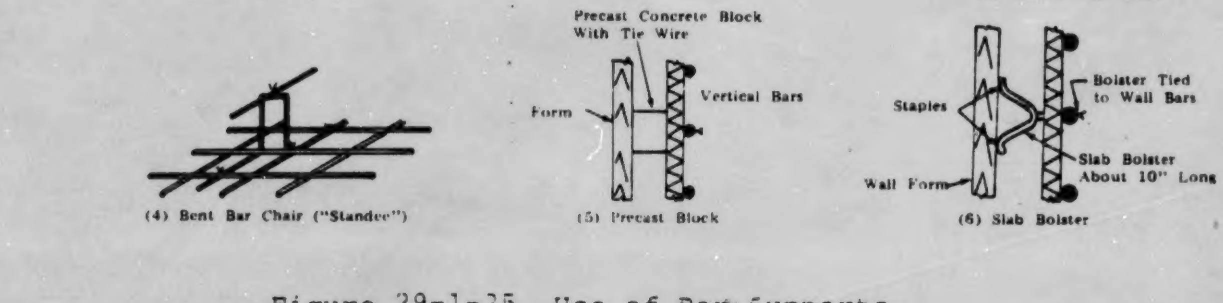
Size as shown.

(3) Precast Concrete Doweled Blocks

Figure 29-1-24 Precast Concrete Block Bar Supports


Top Mat Support Bar
90° Hook
No. 4 Dowel Bar
Bottom Mat Support Bar
Concrete Block
Top Bar
Bottom Mat Bars

(1) Precast Block (2) Precast Block (3) Special High Chair

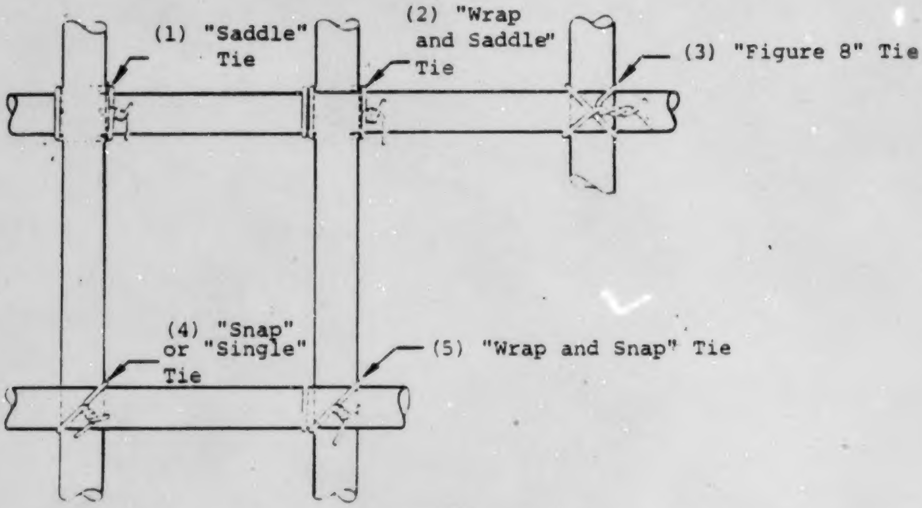

Precast Concrete Block With Tie Wire
Form
Vertical Bars
Staples
Bolster Tied to Wall Bars
Slab Bolster About 10" Long
Wall Form

(4) Bent Bar Chair ("Standee") (5) Precast Block (6) Slab Bolster

Figure 29-1-25 Use of Bar Supports

The tying of bars is essential to maintain their position during concrete placing and work done by other trades. The tying of bars does not add to the strength of the structure, but the correct position of each bar does. It is usually adequate to tie every 4th or 5th intersection.

The wire usually used for tying reinforcing bars is #16 gauge black soft annealed wire, carried in coils on holders or reels. Various types of ties are used, but the more common ones are illustrated in Figure 29-1-26.



(1) Used for securing column ties to vertical bars, or securing footing or other mats
(2) Used where a great strain is placed on ties
(3) Used occasionally in walls
(4) Most commonly used for flat, horizontal work
(5) Most commonly used for wall reinforcement work

Figure 29-1-26 Wire Ties

Two examples of re-bar installation are shown in Figure 29-1-27.

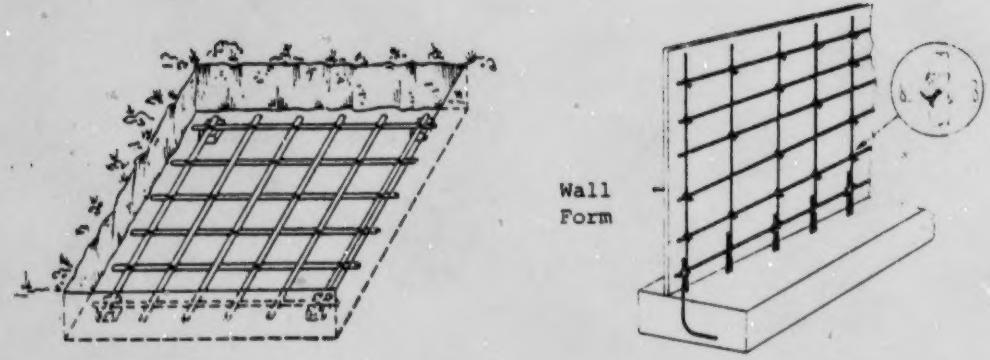


Figure 29-1-27 Re-Bar Installation

Re-bar splices are frequently made by lapping (wiring or tying), welding or with mechanical couplings. Users are cautioned, however, that when spot or tack welding is performed on re-bar, localized heating and arcing may cause a "notching effect" and reduce the strength of the affected material as much as 30-35%. On nuclear projects, usually the only welding permitted on re-bar is for splicing work using the "Thermit" process where the bar ends are placed in a mold or sleeve with a small gap between. The new material (molten steel) flows into the mold and fuses to and around each end of the bar. This process produces a spliced area stronger than the bar itself.

Inspection of reinforcing steel is one of the most important steps in obtaining a satisfactory and acceptable job. The person performing the inspection must be knowledgeable in, and prepared to interpret and explain the applicable plans and specifications.

Before re-bar is placed, the following items should be checked by the inspector:

1. Only approved, latest revision drawings being used.
2. Reinforcing bars are of correct grade and size.
3. Bar supports are correct types, as specified.
4. All required test reports have been received, and are acceptable.

During the placing of bars, the following items should be checked:

1. Number of pieces, size, length, shape and grade of all bars in each structural member.
2. Concrete cover between forms and steel bars.
3. Type, finish, height and location of bar supports.
4. Proper positioning and tying of bars.
5. All splices for acceptability.

Additional information about reinforcing steel usage is available from the Concrete Reinforcing Steel Institute (CRSI).

Embedments are parts such as structural anchors, drain piping, and sleeves which are set in place permanently, surrounded by concrete. Such items are located, set in place and secured within the form before the concrete is placed. They may be wired to re-bar, attached to steel chairs or other support steel, or blocked with pre-cast concrete block spacers. Embedments must be located and arranged accurately as they usually attach or align with other equipment, piping or a structure later in the construction sequence. Embedments should be checked for location and alignment by the inspector along with the re-bar pre-placement inspection.

All inspection operations described in this section may be assigned to a qualified QA/QC technician.

CONCRETE PRODUCTION, PLACEMENT AND CURING

The selection of concrete proportions involves a balance between reasonable economy, and requirements for strength, placeability, durability, and sometimes, appearance. For projects such as nuclear power plants, all concrete is produced to precise specifications which have been proven by mixing and physically testing concrete samples comprised of the representative materials. The various formulations of mixes are called "design mixes".

A typical design mix for foundation mat concrete having an average 28 days compressive strength of 3500 psi, may require the following batch weights per cubic yard of concrete:

water (mixing):	343 lb.
cement:	553 lb.
coarse aggregate (dry):	1896 lb.
fine aggregate (dry):	1203 lb.

When concrete is batched then to this design mix, these proportions of materials will be used. For example, to "batch" a 9 cubic yard load in a transit mix truck, the following quantities would be used:

water: 9 x 343 lb. = 3,087 lb.
cement: 9 x 553 lb. = 4,977
coarse aggregate: 9 x 1896 lb. = 17,064
fine aggregate: 9 x 1203 lb. = 10,827
Total Weight 35,955

Concrete batch plants are sized to produce concrete at a certain nominal rate, i.e. cubic yards per hour. A typical batch plant on a nuclear construction project may be rated at 250 cubic yards per hour. This rating is the approximate maximum rate at which it is capable of batching concrete. This rating is then used to calculate the rate of component materials usage, and the time required to produce the concrete for large pours. For example, the placement of a large foundation mat requiring 1500 cubic yards of concrete is being planned for a monolithic pour (poured continuously in a single unit).

1. What is the minimum time required to batch the required concrete? Divide the amount of concrete required by the production rate of the plant: 1500 cubic yards ÷ 250 cubic yards/hour = 6 hours required.
2. Using the proportions listed for the 3500 psi concrete design mix, how much cement and aggregates will be required in tons? Design mix, quantities per cubic yard:

Cement:	553 lb.
Coarse aggregate:	1,896 lb.
Fine aggregate:	1,203 lb.

Materials required for pour:

Cement: (553 lb./yd. x 1500 cu. yds.) ÷ 2,000 lb./ton = 414.75 tons

Coarse aggregate: (1896 lb./yd. x 1500 cu. yds.) ÷ 2,000 lb./ton = 1,422 tons

Fine aggregate: (1203 lb./yd. x 1500 cu. yds.) ÷ 2,000 lb./ton = 902.25 tons

Before the concrete batching and placement operation is started, it must be verified that sufficient quantities of materials are on hand, and all necessary equipment is functional and in proper adjustment or calibration. A final inspection of the placement area and forms should also be made to verify proper cleanliness and freedom from obstructions.

During the concreting operation, continuous inspection should be performed. The major items that affect the ultimate concrete quality, and require attention are outlined below:

- Working conditions - Adequate lighting. Provision for covering and protection from weather.
- Batching - Proportioning of materials. Proper equipment operation. Accurate control of water addition.
- Mixing - Proper mixing time (not overmixed). Delay of batches in mixer.
- Control of consistency - Observation of concrete being placed. Adjustments in mix. Tests.
- Control of air content - Use of admixtures. Control of mixing time.
- Conveying - No segregation of materials. No excessive stiffening or drying out.
- Placing - Observe for uniform, dense concrete. Maintain continuous operation. Do not exceed maximum vertical drop. No dropping against forms or reinforcement. Disposition rejected batches.
- Consolidation (vibration) - Thorough and uniform consolidation.
- Finishing of unformed surfaces (e.g. floor slabs) - Alignment of surfaces. Proper surface layer of mortar. Final troweled surface.

Curing of the concrete starts immediately after finishing or initial set. Moisture must be retained in the concrete during the hydration of the cementitious materials (hardening) so that the desired strength and other properties of the concrete are developed. An adequate quantity of mixing water is normally in the concrete at the time of placement, but water is lost through evaporation and absorption by aggregates and forms.

The two general methods employed for curing are (1) maintaining a moist environment from the continuous or frequent application of water, and (2) the prevention of water loss by means of sealing materials.

The first method, known as water curing, may be accomplished by "ponding" (or flooding) of the surface, water fog spraying or sprinkling, or covering the surface with an absorbent material such as burlap or cotton mats and spraying occasionally with water.

Sealing materials are sheets or membranes of plastic film, waterproof paper or liquid membrane forming compounds placed on the concrete to reduce the loss of water.

Additional protection is needed for the concrete under extreme weather conditions. In cold weather, protection from freezing may be secured by insulation with layers of dry, porous material such as straw or hay or commercial insulating material. In hot weather, the need for adequate continuous curing with moisture is greatest during the first few hours after placement of the concrete, to avoid rapid drying.

FORM REMOVAL AND SURFACE FINISHING

The recommended time of removal of forms and shores is usually specified by the architect-engineer. Premature removal may cause failure of or injury to the concrete which may not have attained full strength. Supporting forms and shores must not be removed from beams, floors and walls until these structural units are strong enough to carry their own weight and any approved superimposed load. Where reuse of forms is planned, it is desirable to remove the forms and shores as early as possible.

In warm weather, early form removal permits specified curing work to begin. The exposure of "green" concrete (partially cured) also permits surface repairs or treatment to be performed more easily due to the favorable bonding surface. In cold weather, the forms provide insulating protection from the cold and should be left in place longer, thereby minimizing the effects of thermal shock and subsequent damage to the concrete.

Forms should be constructed and erected in such a way to permit easy removal or "stripping". Stripping requires considerable care on the part of workmen to avoid damage to the green concrete, which can be marred by scratching and chipping. Forms should be handled carefully to extend useful life. Form panels should not be dropped, but should be handed down or lowered on ropes, cables or other devices to avoid damage. Curing procedures should start immediately when the forms are removed.

It is usually necessary to fill or repair voids and imperfections in formed concrete surfaces. Holes are left from form-tie removal, and imperfections may result from ineffective vibration during concrete placement. The most commonly found surface defects are:

1. "honeycomb" - exposed coarse aggregate particles forming a cell-like structure. Caused by poorly mixed concrete, not adequately puddled with cement mortar.
2. entrapped air voids - surface pits or holes resulting from trapped bubbles of air.
3. "sand streaking" - fine granular or porous streak-like areas, resulting from a deficiency or washing-out of fines or cementitious materials.
4. "pour lines" - dark, stain-like lines showing on the formed surface demarking the boundary of adjacent batches or "lifts" of concrete.

Serious "honeycomb" or other extensive porous surface conditions may have to be chipped out and repaired, but it usually is acceptable to repair the area by troweling on a mortar mixture. In some cases, specifications are written which require that all exposed concrete surfaces be final finished uniformly, for appearance, by rubbing on a thin mortar mixture consisting of cement, sand and water.

Additional information on concrete placement, finishing and curing is presented in Module 29-4. Concrete inspection and testing operations, which are frequently handled by QA/QC technicians are covered in Module 29-5, Concrete Testing and Inspection.

STRUCTURAL FILL MATERIALS AND INSTALLATION

The term fill is used to designate all man-made deposits of natural soil or waste materials. The term structural fill indicates that the filled area may be required to support some type of structure, such as a floor slab or road paving. The term backfill generally refers to the fill material replaced in trench type excavations and foundation excavations along walls, to bring the ground elevation up to the original or the designated finished grade.

Natural soils, which are free from rubbish and organic materials such as limbs and roots, and which compact easily, are usually required for the structural fill materials used on projects such as nuclear plant construction.

The principal types of soils may be divided into two classes according to the sizes of the grains of which they are composed. The coarse grained soils are sands and gravels, and the fine grained soils are silts and clays. Soils may be comprised of mixtures of these materials, and may contain organic material such as peat.

Most sands and gravels are composed of grains of quartz or silicon dioxide, but may be granite, basalt or other rocks. The grain shapes may be rounded or angular, and packed tightly together in dense deposits.

Clay particles are extremely small, and are composed primarily of hydrous aluminum silicate. The particle shape is flat or flake-like and forms a deposit in the form of a network or mesh of solid grains with the intervening spaces, called voids or pores, filled with water.

Silts are usually composed of minute particles of silicon dioxide and are rounded in shape.

The specific gravity of different soil particles is quite uniform, generally falling between 2.5 and 2.8. Soil density, however, may vary from about 70 lbs /cubic feet to over 150 lbs/cubic feet, because of the differences in voids in the soil, depending on the grading of the grain sizes; the moisture content; or the extent to which it has been consolidated or compacted by rolling, tamping or vibrating.

The permeability of a soil, (i.e., its ability to permit water to pass through its pores or voids), has a marked effect on the way the soil compacts and the rate at which it compresses under structural loads. Sand offers little resistance to the passage of water because of its permeability, and the final degree of compression is reached almost as soon as the load is applied, even though the pores may be filled with water. Clay, however, is quite impermeable and the pores of natural deposits are normally filled with water so that compression takes place very slowly and continues over a long period of time.

Swelling and shrinking are frequently characteristics of clay soils which preclude their use as structural fill materials. The volume of clay soils tends to change as the moisture content changes, even though there is no change in the external load to which it is subjected. Such changes in volume are brought about by stresses set up by capillary action in the pores of the soil; an increase in volume is called swelling, and a decrease in volume is called shrinking.

Fill material must be installed and compacted correctly if it is to remain stable and provide the required strength characteristics. Normally, fill should be placed in level, even layers of 6" to 12" of depth. Each layer is compacted by hand tamping, mechanical tamping with one-man gasoline engine powered "whackers", or rolling with heavy specially cleated rollers called "sheeps foot rollers", or tractors equipped with cleated wheels. Each layer of compacted fill is usually tested to assure that the required degree of compaction or soil density has been obtained before proceeding with the placement of successive layers.

In addition to the scrapers or bulldozers usually used for placing fill, and rollers for compacting the fill, sprinklers are needed for adding water to the fill material as necessary. Water replaces much of the air in the voids in the soil, and, being noncompressible, produces a denser soil state for a given degree of compactive effort.

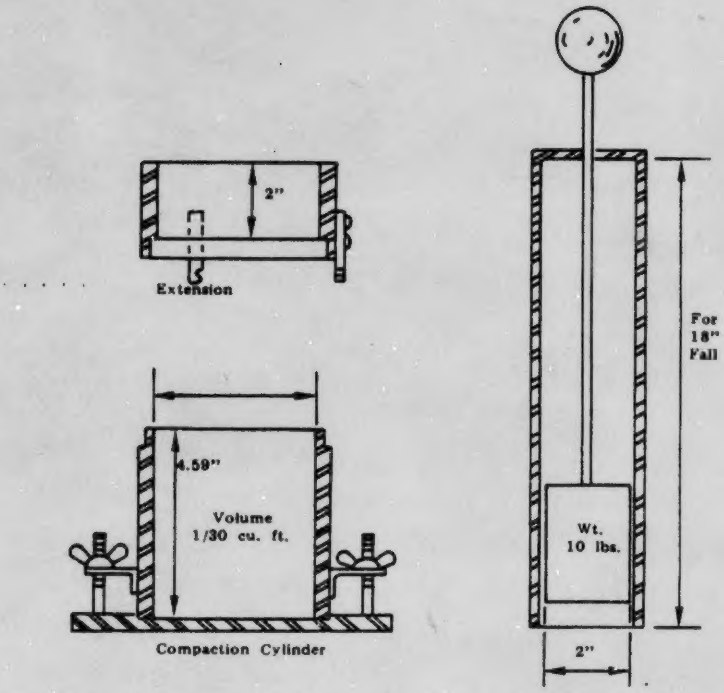
SOIL TESTING

During the placement and compaction of fill materials, various soils tests may be employed to monitor the effectiveness and acceptability of the structural fill operations.

The tests which are generally used have been standardized and published by the American Society for Testing and Materials (ASTM), and are described in this section.

The strength characteristics of compacted fill soils are related to the void ratio or dry density of the soil. Foe each type of fill material, there is a specific water content that will enable a certain void ratio or dry density to be achieved with the least amount of compaction or effort. The water content that will allow the densest compaction under a given compactive effort is known as the optimum moisture content. The optimum moisture content for fill soil materials is usually determined by the "Modified Proctor Test".

For the Modified Proctor (Compaction) Test, the test apparatus consists of (1) a standard brass cylinder mold with a machined base which forms a bottom for compacting soil in the mold, (2) a removable extension which fastens to the top of the mold to hold the soil during compaction, and (3) a standard hammer having a milled face and weighing 10 lbs. This equipment is illustrated in Figure 29-1-28, and is arranged to allow the hammer to free fall exactly 18 inches to the surface cf the soil in the mold. The soil sample is placed in the mold in 5 separate "lifts" (or layers), and each lift receives 25 blows of the hammer. The test is repeated on additional samples of the soil, with additional water added to the soil sample each time the test is repeated. For each trial, the wet and dry densities. and void ratios are computed. The unit dry densities and void ratios are then plotted against water content for each sample, and the optimum water content estimated from the resulting curve. (Please refer to the next page for Figure 29-1-28.)



Compaction Cylinder (Standard Mold)   Compaction Hammer

Figure 29-1-28 Modified Proctor (Compaction) Test Apparatus

As a general procedure, an experienced inspector on a project usually develops a "feel" for the soil being compacted and can tell by rubbing the soil in his hands and by observing the behavior of the soil under the operation of the construction equipment and the rollers whether the soil is too wet or too dry, or is at the desired moisture content. For example, if the soil springs under the roller and deflects a significant amount, the moisture content is too high. If the sheepsfoot rollers tend to ride out on the first couple of passes, the moisture content is too low. This ability to estimate moisture content in relation to optimum is usually developed during the early periods of a job by making a large number of moisture-content determinations and correlating the results with the observed soils behavoir.

The compacted density of the soil may be determined in several ways. The most commonly used methods involve weighing a known volume of compacted soil. A more recent method is a nuclear technique utilizing a gamma source and a gamma detector. The nuclear method (ASTM Designation: D2922) involves placing the source and detector either on, into or adjacent to the material under test, measuring the transmitted or back scattered radiation, and correlating the results with a suitable calibration curve. The values obtained are expressed in units of total or wet density.

The technique of weighing samples is usually done by either the sand cone method (ASTM Designation: D1556) or the rubber-ballon method (ASTM Densignation: D2167).

The sand cone method consists of excavating a hemispherical hole in the surface to be tested, collecting the excavated material, weighing the excavated material, and determining the volume of the removed soil by pouring calibrated sand into the hole. The apparatus is illustrated in Figure 29-1-29, and consists of (1) a steel plate with a hole approximately 4 inches in diameter in the center, (2) a hollow cone which fits over this hole and with a fruit jar connection above, and (3) a 1-gallon fruit jar filled with calibrated sand (sand of uniform particle size and known density). Between the cone and the fruit jar there is a valve which allows sand to run down from the fruit jar into the cone below. Before using the apparatus, it must be calibrated to determine the unit weight of the sand in the jar, and the weight of sand which runs out of the jar in excess of that required to fill the cavity from which the soil sample was removed.

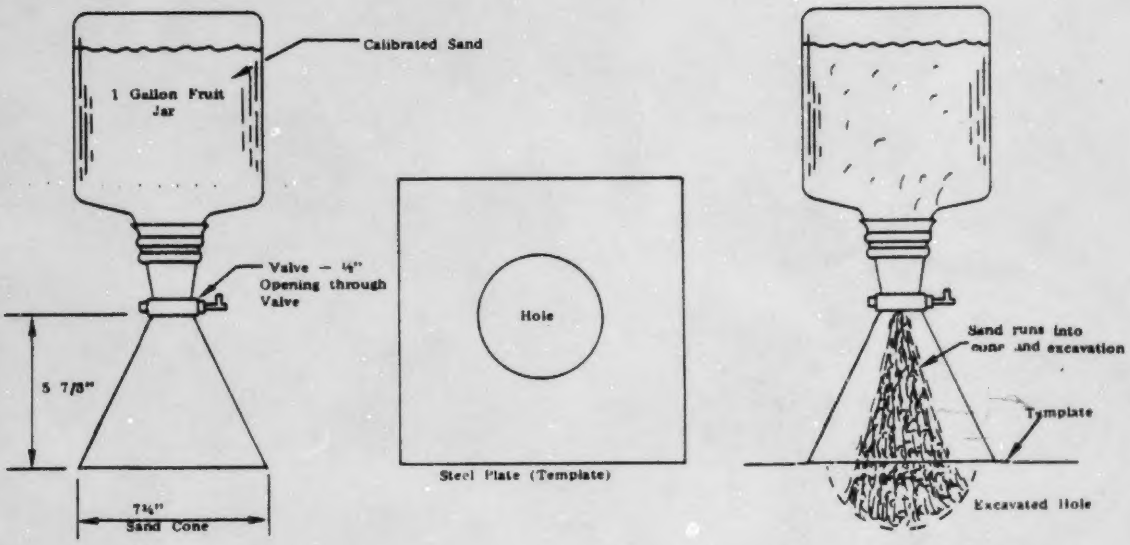

Calibrated Sand
1 Gallon Fruit Jar
Valve — ¼" Opening through Valve
5 7/8"
7¾"
Sand Cone
Hole
Steel Plate (Template)
Sand runs into cone and excavation
Template
Excavated Hole

Figure 29-1-29 Sand Cone Density Apparatus

The rubber-balloon method consists of excavating a test hole, collecting and weighing the excavated material, and measuring the volume of the void by forcing water through the bottom of the test apparatus into a sealed latex balloon into the excavated pit. The apparatus is illustrated in Figure 29-1-30, and consists of (1) a steel plate (template), (2) a graduated glass or lucite cylinder enclosed in an airtight aluminum case with an opening in the bottom sealed by a balloon, (3) water in the cylinder, and (4) a double acting rubber bulb attached to the bottom of the cylinder for applying either a pressure or a vacuum to the inside of the cylinder with the apparatus positioned over the test location, the volume of water in the cylinder is read before and after the excavation is performed. The difference in volumetric readings represents the volume

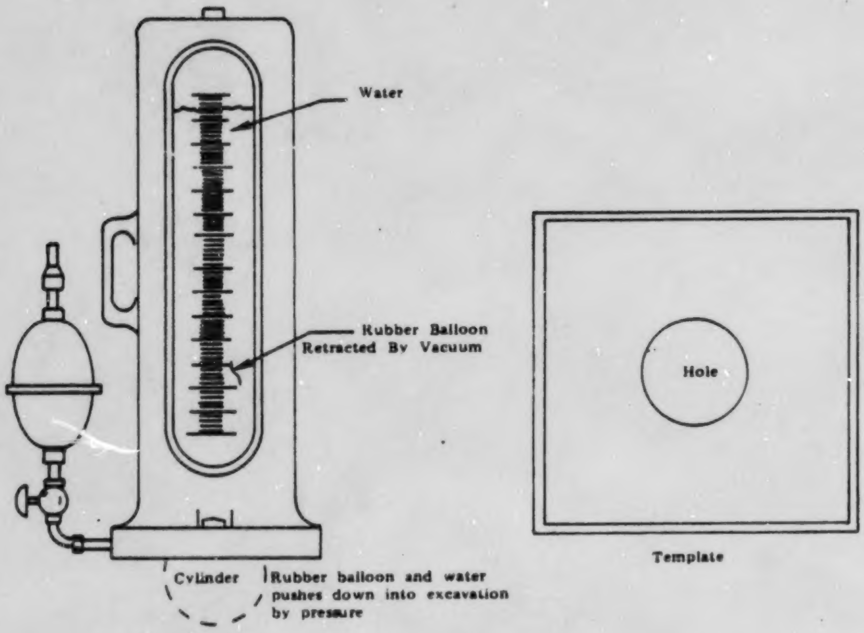

Water
Rubber Balloon Retracted By Vacuum
Hole
Template
Cylinder
Rubber balloon and water pushes down into excavation by pressure

Figure 29-1-30 Rubber Balloon Density Apparatus

of the excavated test pit. The density of the fill material is then calculated from the test data.

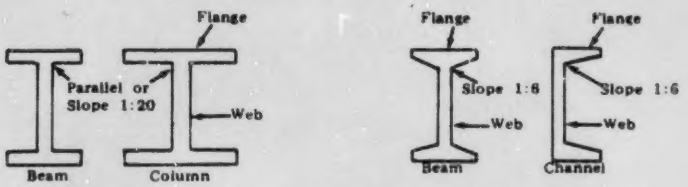
In all of these density tests, after the density is obtained, the value is compared with the maximum density obtained in the laboratory compaction test ("Proctor" test) to determine the percentage of (maximum) density. Layers that are not compacted to the specified percentage must be given additional compaction.

The QA/QC technician may function as an inspector for all fill, compaction, and soils testing operations. In this capacity, he may be required to:

1. monitor the fill material usage
2. monitor the proper placement of fill
3. monitor compaction techniques
4. perform appropriate compaction/density tests

STRUCTURAL STEEL ERECTION

The term structural steel is used to describe steel columns, beams, girders, trusses and other structural units used in building and bridge construction, which are fabricated by riveting, welding, or bolting together various types of rolled steel shapes or sections. Typical rolled steel shapes are illustrated in Figure 29-1-31.


Flange
Parallel or
Slope 1:20
Web
Beam
Column
Flange
Slope 1:6
Web
Beam
Flange
Slope 1:6
Web
Channel

Wide Flange Sections American Standard Sections

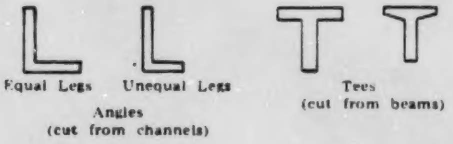

Equal Legs
Unequal Legs
Angles
(cut from channels)
Tees
(cut from beams)

Figure 29-1-31 Types of Rolled Steel Sections

Structural steel members are usually prefabricated and delivered to the job site ready for installation. Care should be taken in unloading members, since poor practices such as using connection angles or plates for lifting points, or dragging members from trucks or flat cars from one end only may impose overstressing, resulting in kinks or misalignment. Members should not be dropped or impact loaded.

All fabricated steel members should be checked for size and shape against the applicable shop drawing before erection. The type of connectors should be reviewed before erection starts, and the members should be free of kinks, bends, and other distortions. Other checks that should be made before erection are:

1. surface preparation and coating, where required
2. proper milling of column ends, where required
3. proper holes sizes, number of holes, and layout of connections

Most field connections are now made with either high-strength bolts or welding. Before bolts are inserted, members are aligned and matching holes are brought into matching positions by means of one or more drift pins. A drift pin is a tapered steel rod which is driven into a hole. Poor connections with poorly matching holes are not acceptable, and are usually rejected.

Members which are connected by welding are aligned with welding clips and wedges, "come-a-longs" (portable geared winches with cables), and other devices.

Trusses are triangular shaped modules connected into a structural framework used to span large areas without intermediate support (supported at ends only). Large trusses may be shipped to a job site in sections, and are usually preassembled before erection. Lateral stability of trusses may be a problem, and, if handled roughly or improperly, will have a tendency to twist or bend sideways during erection.

Purlins are beams spanning from truss to truss, and are used for ceiling or roof construction. Purlins are relatively light shapes and must be handled carefully to avoid damage.

Bolting of structural steel is normally done only with high-strength bolts. The high-strength bolt is identified by three radial marks on the head and three long indented marks on the nut. The bolt is used with a washer on the side of the element that is turned, and all of the elements are made of high carbon steel. High tensile bolts are usually driven with precalibrated impact wrenches to the required torque value. It is considered good practice to inspect bolt installation and check the bolt tension of between 5% and 10% of the installed bolts, with a separate calibrated wrench. High-strength bolts should not be reused, since they do not develop design strength in this situation.

As erection work progresses, lower members are "plumbed", and their connections tightened. Permanently bolted connections should have a bolt in each hole, and heavy members temporarily fastened should be held with at least four bolts. Final operations include the removal of guy wires used for supporting and plumbing during erection, final inspection of connections, and the removal of temporary safety devices, such as railings, nets, scaffolds and planked floors.

The QA/QC technician may function in the capacity of a steel erection inspector. The following list summarizes the various items that he may check or inspect during the various erection operations:

1. check prefabricated members for shape, size and configuration
2. check shop painting for proper covering, scale, rust, and abraded areas
3. monitor contractor's lifting and handling operations of prefabricated members
4. monitor plumbing and bolt-tightening operations
5. inspect bolted connections

6. inspect high-strength bolting with calibrated wrench for proper torquing
7. review the test calibration of high-strength bolt wrenches on a daily basis

EXERCISES

1. A nuclear power plant is planned to be built on a site with the following characteristics:
   a. Area flat, lightly forested with heavy undergrowth.
   b. Elevations: existing ground level - 100'
      water table - 88'
      shelf rock - 80'
      lowest excavation - 60'
   c. Soil type: sandy, highly permeable.

   Listed below are various construction operations which are usually performed prior to concrete placement. Number the operations starting with "1" in the chronological order in which they typically occur:

   ____ connection of utilities
   ____ dewatering
   ____ grubbing
   ____ access road construction
   ____ established safety program - medical, fire protection
   ____ temporary construction buildings
   ____ excavation
   ____ logging, tree removal
   ____ railroad siding construction

____ swamping
____ top-soil removal
____ parking lot construction

2. The design mix for a particular batch of concrete requires the following materials:

water	325 lbs.
cement	550 lbs.
coarse aggregate (1")	1900 lbs.
fine aggregate	1200 lbs.

The batch plant has the following scale capacities:

water	2000 lbs.
cement	2500 lbs.
coarse aggregate (1½" or smaller)	6000 lbs.
fine aggregate	5000 lbs.

a. Calculate the batcher tolerance for each scale, based on scale capacity:

water ________
cement ________
coarse aggregate ________
fine aggregate ________

b. Calculate the batcher tolerance for each scale, based on batch weight:

water ________
cement ________

coarse aggregate	________
fine aggregate	________

3. A concrete batch plant is rated at a nominal output of 200 cubic yards per hour. For a particular placement of 1600 cubic yards, the following design mix will be used:

Water	350 lb./yd.^{3}
Cement	600 lb./yd.^{3}
Coarse Aggregate	1,800 lb./yd.^{3}
Fine Aggregate	1,300 lb./yd.^{3}

At the nominal output rate of the plant,

a. How much time is required to batch the concrete for the placement? ________________

b. What is the hourly rate of usage of each of the component materials?

Water	________
Cement	________
Coarse Aggregate	________
Fine Aggregate	________

c. What is the total quantity of cement needed?

____

4. List 5 factors that should be observed during concrete placement operations which affect the ultimate strength of the concrete.

5. Describe the concrete curing process, what occurs, and why curing procedures are necessary.

6. Explain where slip forms are generally used.

7. What are prefabricated panel forms used on large projects for wall construction?

8. What is the purpose of the concrete cover over the re-bar?

9. Improper welding on re-bar may produce a "notching effect". Explain how this affects its strength.

10. Does the tying of re-bar add strength to the structure? Explain.

11. Explain what is meant by the "Honeycomb" which may occur in concrete.

12. Name two general classes of soils and give two examples of each.

13. What characteristics of clay make it a poor structural fill material.

14. What is the usual recommended procedure for placing and compacting fill?

15. Why is the moisture content of fill so important?

16. What test can be used to measure soil compaction, with the results expressed as a percent maximum density?

17. Describe the physical difference between a typical wide flange beam section and a similar sized American Standard beam section used in structural steel construction.

18. Why are calibrated wrenches used to tighten high-strength bolts?

19. Visit a construction site where clearing and grubbing operations are taking place. Prepare a report as described in Procedure #1 of the Procedures section of this module.

20. Visit a concrete company which uses a stationary mixer. Prepare a report on your visit as described in Procedure #2 of the Procedures section of this module.

MATERIALS

None.

PROCEDURES

1. Visit a construction site as requested in Exercise #20 where clearing and grubbing operations are taking

place. Prepare a report including the following information:

a. Data
b. Site Location
c. Type of plant or building currently under construction
d. Description of any excavation and grading work
e. Type of equipment employed in excavating
f. Check conformance to such site drawing requirements as location, elevation, slope, and removal of loose materials
g. Description of any de-watering and drainage operations taking place
h. Any discussions with construction foreman or QA inspectors at the plant site.

2. Visit a concrete company as requested in Exercise #21 which uses a stationary mixer. Prepare a report on your visit which includes the following information:
   a. Data
   b. Location of cement company
   c. Examination of cement batcher
   d. Examination of aggregates
   e. Amount of water added to a given batch
   f. Description of batching equipment (manual, semi-automatic or automatic)
   g. Any discussion with plant personnel, foreman or QA inspectors.

DATA TABLE

None.

REFERENCE MATERIALS

ACI Manual of Concrete Practice, American Concrete Institute, Detroit, MI

Materials Design and Control of Quality Concrete, Protex Industries Inc., Denver, Colorado

Control of Quality of Ready-Mixed Concrete, National Ready-Mixed Concrete Assoc., Silver Spring, MD.

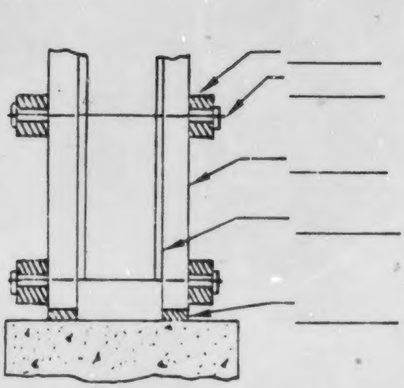
Placing Reinforcing Bars, Concrete Reinforcing Steel Institute, Chicago, Illinois

TEST

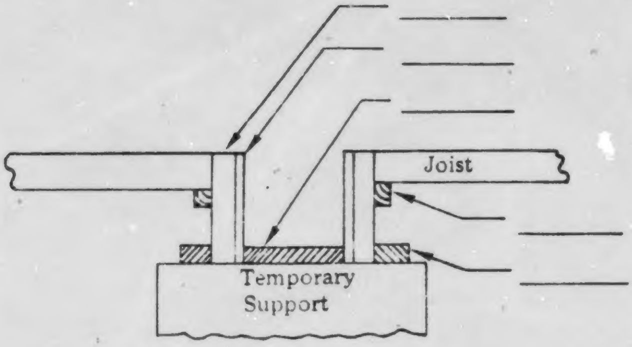
A. Complete the following statements:

1. Concrete derives its strength from ______________.
2. A central mixing plant has the advantage of providing better control of the addition of ________ ___________.
3. Transit mixing provides better control of _______ ___________.
4. The simultaneous loading of dry concrete materials in a mixer is called ____________________.
5. Operator skill is most important in the operation of ________________ batchers.

B. Label the indicated parts on the forms below:



Wall Form Section



Beam Form Section

C. Mark the following statements true or false:

____ 1. Slip forms are usually used for horizontal decks.

____ 2. Concrete slabs may be cast on elevated sheathing-type forms.

____ 3. Cleanout doors or panels are usually provided in column forms for removing concrete which fails to harden.

____ 4. Prefabricated panel forms are used on large projects for wall construction.

____ 5. Snap ties are frequently used to secure side panels to wales.

____ 6. The wall form sill is usually the last form component to be installed.

D. Complete the following statements:

1. Concrete cover over re-bar protects the steel from ____________, ____________ and ____________.
2. Reinforcing steel is used to strengthen concrete in areas which are in ______________.
3. The minimum concrete cover usually required for re-bars installed in slabs is ________________.
4. ______________ are used to support re-bar at the proper elevation and position in concrete forms.
5. Precast concrete blocks are usually installed in contact with the ____________ and the __________.
6. Improper welding on re-bar may produce a ________ _______ _____________.
7. The "tying" of re-bar does not add _____________ to the structure.
8. Using standard practice in placing bars in a floor slab, a bar designed to be located 2" from the form should fall between the dimensions _________ ___________.
9. Tension cracks are most likely to occur in a concrete slab on the ______________ side, between structural supports.

10. Proper positioning of re-bar in concrete, is critical to the ____________ of that part of the structure.

E. Mark the following statements true or false:

____ 1. Forms should always be removed as soon as possible to minimize sticking, especially in cold weather.

____ 2. Partially cured concrete is known as "green" concrete.

____ 3. "Honeycomb" may occur when concrete is poorly mixed.

____ 4. Surface blemishes on stripped concrete are usually chipped out and repaired.

____ 5. "Sand streaking" may result when coarse aggregate is inadequately puddled with cement and water.

F. Answer the following questions:

1. Name two general classes of soils, and two examples of each.
2. The variability in soil densities is caused by what factor?
3. Clay soils usually make poor structural fill material due to what characteristics?
4. What is the usual recommended procedure for placing and compacting fill?
5. Why is moisture content of fill soil important?

G. Mark the following statements true or false:

____ 1. The optimum water content of soils for the densest compaction is usually determined by the Modified Proctor Test.

____ 2. The rubber balloon test is used to measure soil compaction, with results expressed as % maximum density.

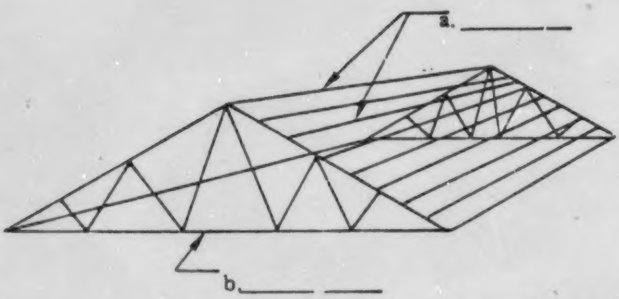
____ 3. In performing the sand cone test, a test hole is excavated and the excavated soil is discarded.

____ 4. An advantage of the sand cone test is that no calibration is required.

____ 5. In performing the Modified Proctor Test, the operator should carefully fill the compaction cylinder and the extension before compaction begins.

H. Answer the following questions:

1. Identify the indicated parts in the simple structure shown below:



Roof Structure

2. Describe the physical difference between a typical wide flange beam section and a similar American Standard beam section.
3. _____________ are frequently used in aligning holes in mating steel sections during bolting operations.
4. How may high-strength bolts and nuts be identified?
5. Why are calibrated wrenches used to tighten high-strength bolts?

6. Mark the following statements true or false:

____a. The inspection of high-strength bolt tightening operations should include the physical check of the tension on a sample of the installed bolts.

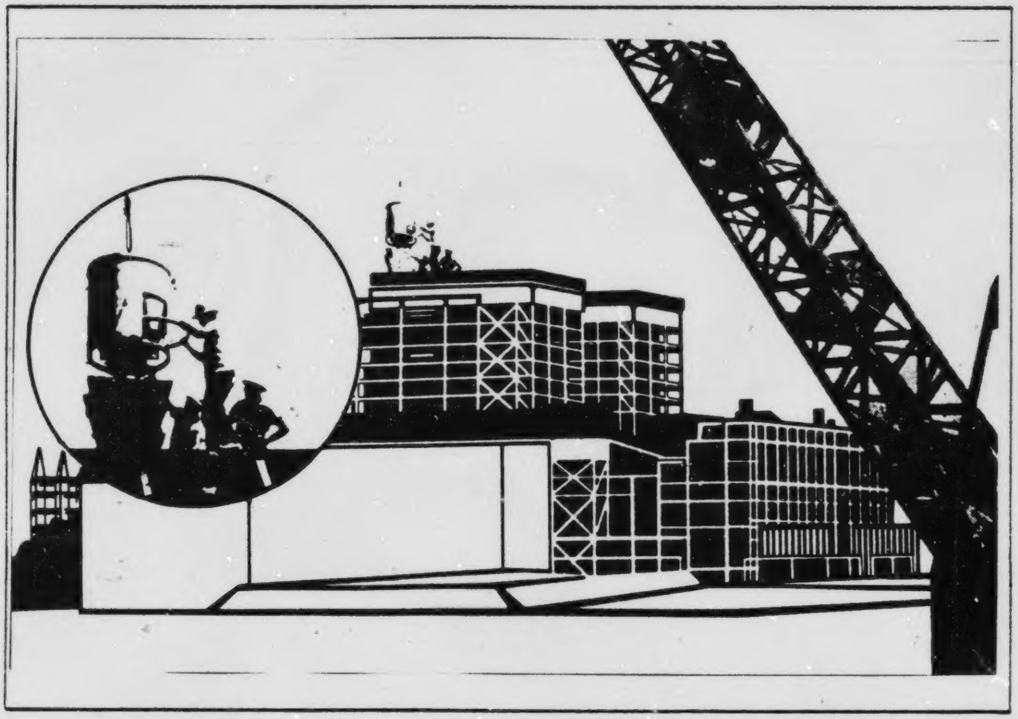
____b. High-strength bolts are expensive and should be salvaged for re-use.

____c. When holes do not match in mating sections, it is acceptable practice to drill them out as large as necessary to accomodate the bolt.

NUCLEAR TECHNOLOGY

MODULE 29-2

STRUCTURAL STEEL MATERIALS, INSTALLATION, AND INSPECTION



COURSE 29 CIVIL/STRUCTURAL INSPECTION

CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

4800 LAKEWOOD DRIVE WACO, TEXAS

COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

MODULE 29-1	Inspection of Construction Operations
MODULE 29-2	Structural Steel Materials, Installation and Inspection
MODULE 29-3	Concrete Materials
MODULE 29-4	Concrete Preparation, Production, Placement and Finishing
MODULE 29-5	Concrete Testing and Inspection
MODULE 29-6	Prestressed Concrete Materials, Fabrication and Inspection

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INTRODUCTION

On large construction projects, a qualified QA/QC technician functions as a structural steel inspector and is responsible for materials acceptance and installation inspection. The term structural steel is used to describe steel columns, beams, girders, trusses and other structural units used in building and bridge construction. Structural steel members are fabricated by riveting, welding, or bolting together various types of rolled steel shapes or sections, such as channels, H-beams, angles and tees.

This module describes the materials used in structural steel work; the standards to which materials are purchased and inspected; fabrication, handling and installation practices; and the various inspection tasks performed during erection operations.

MODULE PREREQUISITES

The student/trainee should have prior training or experience in inspection of construction operations. Completion of Module 29-1, Inspection of Construction Operations, satisfies this prerequisite.

OBJECTIVES

Upon completion of this module, the student/trainee can:

1. Demonstrate a knowledge of structural steel materials and specifications requirements by performing the following:
    a. Given sample chemical and physical test reports on specimens representing two types of structural steel materials, (1) compare reported results with given specification requirements, (2) identify nonconforming characteristics, and (3) determine the acceptability of the materials.
    b. Given the inspection results for a group of steel shapes inspected for straightness, (1) compare the results with specification requirements, (2) calculate the permissible camber for each member, and (3) determine the acceptability of each member.
2. Identify the basic members of a simple structural steel roof support structure.
3. Describe methods of cutting steel parts and preparing bolt holes.
4. State the purpose of temporary protective coatings on steel members.
5. Describe site storage conditions for steel members.
6. Describe alignment techniques of members for erection.
7. Describe riveting operations.
8. Describe "turn-of-nut" method of tensioning of high-strength bolts.
9. Name the structural steel welding specification.
10. Describe receipt-inspection operations including the basic examinations performed, purpose of test reports, and how acceptability of material test reports is determined.
11. Describe final inspection of bolted fasteners including sample size and actions taken when acceptance criteria are not met.

SUBJECT MATTER

MATERIALS STANDARDS

Chemicals and Physicals

Structural steel shapes are normally supplied by the steel manufacturers to a quality grade known as "structural quality". The type of steel most commonly used for structural purposes is a carbon steel specified as American Society for Testing and Materials (ASTM) A36, Standard Specification for Structural Steel. A36 steel has high strength, high ductility, great stiffness, and is highly resistant to wear and abrasion. A36 steel, on the other hand, rusts readily in damp or corrosive environments, and loses strength and stiffness at high temperatures (i.e., above 800°F.)

ASTM Standard A36 specifies chemical and physical requirements for the material. For structural shapes, the chemical and physical requirements for A36 steel are listed in Tables 29-2-1 and 29-2-2:

TABLE 29-2-1. ASTM A36 Steel, Chemical Requirements

Carbon, max. %	0.26
Phosphorous, max. %	0.04
Sulfur, max. %	0.05
Copper, min. % (when copper steel is specified)	0.02

TABLE 29-2-2. ASTM A36 Steel, Physical (Tensile) Requirements

Tensile strength, psi	58,000 - 80,000
Yield point, psi	36,000
Elongation in 8 in., min. %	20
Elongation in 2 in., min. %	21

For structural applications requiring a higher strength material, ASTM A529 steel may be used. A529 steel has a 42,000 psi minimum yield strength, as compared to 36,000 psi for the A36 steel. The chemical and physical requirements for A529 steel are shown in Tables 29-2-3 and 29-3-4.

TABLE 29-2-3. ASTM A529 Steel, Chemical Requirements

Carbon, max. %	0.27
Manganese, max. %	1.20
Phosphorous, max. %	0.04
Sulfur, max. %	0.05
Copper, min. % (when copper steel is specified)	0.20

TABLE 29-2-4. ASTM A529 Steel, Physical (Tensile) Requirements

Tensile strength, psi	60,000 to 85,000
Yield point, psi	42,000
Elongation in 8 in., min. %	19

For either material, A36 or A529, the steel shapes may be purchased to the chemical composition limits, or the mechanical property requirements, or both, as required by the applicable engineering specifications for the particular construction job.

The standard hot-rolled steel shapes are illustrated and described in Figure 29-2-1.

Dimensions and Fasteners

The general dimensional requirements for structural steel shapes are covered in ASTM A6, Standard Specification for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use. This specification provides dimensional acceptance criteria for structural shapes and other structural steel materials, and defines permissible variations. The variations in the finished mill products result from such factors as roll wear, subsequent roll dressing, and temperature variations in the steel materials and rolling equipment.

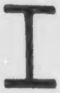
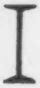
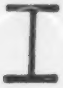
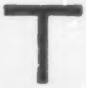
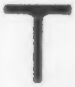
	W Shapes	W shapes have essentially parallel flange surfaces. The profile of a W shape of a given nominal depth and weight available from different producers is essentially the same except for the size of fillets between the web and flange.
	HP Shapes	HP shapes (used for bearing piles) have essentially parallel flange surfaces and equal web and flange thicknesses. The profile of an HP shape of a given nominal depth and weight available from different producers is essentially the same.
	C Shapes (American Standard Channels)	C shapes and S shapes have a slope of approximately 16-2/3% (2 in 12 inches) on their inner flange surfaces. The profiles of C and S shapes of a given nominal depth and weight available from different producers are essentially the same.
	S Shapes	
	M Shapes	M shapes are those which are similar to, but cannot be classified as W, HP, or S shapes.
	MC Shapes (Miscellaneous Channels)	MC shapes are channels which are similar to, but cannot be classified as American Standard Channels.
	Angles Equal Legs	Equal leg and unequal leg angle (L) shapes of the same nominal size from different producers have profiles which are essentially the same, except for the size of the fillet between the legs, and the shape of the ends of the legs.
	Angles Unequal Legs	
	Structural Tees-Cut from W Shapes	
	Structural Tees-Cut from S Shapes	

Figure 29-2-1. Standard Structural Steel Shapes*

* From American Institute of Steel Construction (AISC)

Two types of mechanical fasteners are used in fabricating structural steel members: high strength steel bolts, and steel structural rivets.

The bolts generally used are heavy hex structural bolts, manufactured to ASTM types A325 and A490. A325 bolts are fabricated from steel having a minimum tensile strength of 105,000 psi and minimum yield strength of 81,000 psi. The A490 bolts are quenched and tempered alloy steel bolts fabricated from steel having a minimum tensile strength of 150,000 psi and minimum yield strength of 130,000 psi.

The bolts and nuts are illustrated in Figure 29-2-2, with dimensions listed in Table 29-2-5. A325 bolts are identified on top of the head by three radial lines, the legend "A325", and the manufacturer's symbol. A325 nuts are identified on at least one face by three circumferential marks, or by the number "2", "2H", "D" or "DH" and the manufacturer's mark.

A490 bolts are marked with the legend "A490" and the manufacturer's symbol. Heavy hex nuts for use on A490 bolts are identified with the legend "2H" or "DH" and the manufacturer's mark. A490 bolts may be substituted for A325 bolts, if expedient on the basis of availability, in which case the tension (when tightened) need not exceed that required for the A325 bolts.

Heavy hex structural bolts have shorter thread lengths than other standard bolts. They are selected for use to exclude the thread from all shear planes except in the case of thin outside parts adjacent to the nut, thereby maximizing the shear-working strength of the fastener.

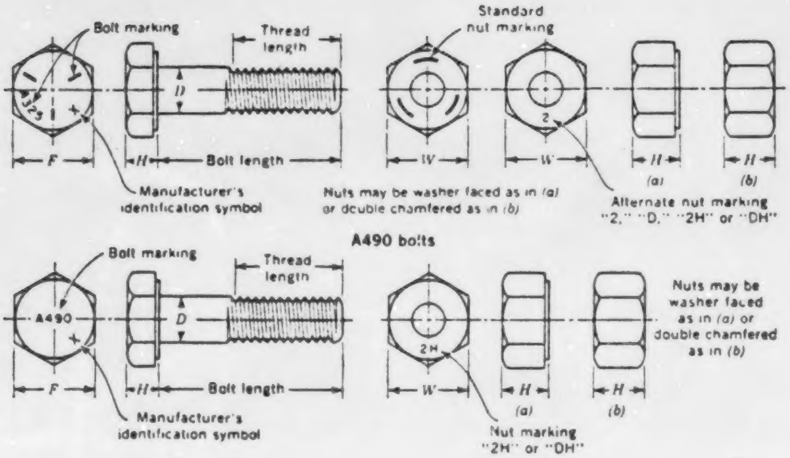

Bolt marking
A325
Thread length
D
Standard nut marking
2
F
H
Bolt length
W
H
(a)
(b)
Manufacturer's identification symbol
Nuts may be washer faced as in (a) or double chamfered as in (b)
Alternate nut marking "2," "D," "2H" or "DH"
A490 bolts
Bolt marking
A490
Thread length
D
2H
Nuts may be washer faced as in (a) or double chamfered as in (b)
F
H
Bolt length
W
H
H
(a)
(b)
Manufacturer's identification symbol
Nut marking "2H" or "DH"

Figure 29-2-2. Heavy Hex Structural Bolts

TABLE 29-2-5. Structural Bolt Dimensions

Nominal bolt size, *D*	Bolt Dimensions, In Inches			Nut Dimensions, In Inches	
	Heavy Hex Structural Bolts			Heavy Hex Nuts	
	Width across flats *F*	Height *H*	Thread Length	Width across Flats *W*	Height *H*
1/2	7/8	5/16	1	7/8	31/64
5/8	1 1/16	25/64	1 1/4	1 1/16	39/64
3/4	1 1/4	15/32	1 3/8	1 1/4	47/64
7/8	1 7/16	35/64	1 1/2	1 7/16	55/64
1	1 5/8	39/64	1 3/4	1 5/8	63/64
1 1/8	1 13/16	11/16	2	1 13/16	1 7/64
1 1/4	2	25/32	2	2	1 7/32
1 3/8	2 3/16	27/32	2 1/4	2 3/16	1 11/32
1 1/2	2 3/8	15/16	2 1/4	2 3/8	1 15/32

The rivets generally used are made to ASTM standard A502 in three grades. Grade I rivets are carbon steel which are for general purposes; Grade II rivets are carbon-manganese steel which are suitable for fastening high-strength steels; and Grade III rivets are similar to Grade II, but with enhanced atmospheric corrosion resistance.

Any of these fasteners are normally purchased to the applicable ASTM requirements, and are furnished with manufacturers' certifications that they meet or exceed all such requirements.

FABRICATION OF COMPONENTS

Structural steel components or members are usually assembled in fabricating shops from standard plates and shapes before being shipped to the construction site.

One of the most common types of prefabricated steel members is the truss. Trusses are triangular shaped modules connected into a structural framework used to span large areas without intermediate support (supported at ends only). Large trusses may be shipped to the job site in sections, and are usually preassembled before erection.

Trusses may be interconnected with relatively light weight members called purlins. Roof support systems are frequently comprised of trusses and purlins.

The operations performed in the fabricating shop in constructing such members begins with laying-out the required parts on plate materials or shapes, and cutting or shearing to correct shape and length. Steel is cut with an oxyacetylene cutting torch or sheared with a mechanical cutting device with a large blade that drops onto the steel to shear it to the proper length. If smoother ends are needed, the cut or sheared surfaces are finished by planing or grinding to a smooth surface. Holes for rivets or bolts are typically drilled. Holes may also be punched and then reamed smooth to provide accurate fastener fit. If connections are to be made by welding, the work is partially done in the shop by "weld-prepping" the member ends (i.e., cutting or grinding the joint surfaces to the correct configuration and size). As a general rule, a maximum amount of work is performed in the shop, to minimize and simplify the riveting, bolting, and welding required at the erection site.

HANDLING AND STORAGE

Prefabricated steel members are usually shop-coated with a light, protective coat of paint to protect the steel until it has been erected and finish-coated or embedded in concrete. Normally the requirement for such painting is written into the purchase specification. Rust and scale should be removed from the members to provide a good bonding surface, followed by the application of an even, uniform coat of paint. If the steel is not coated in this manner, it must be protected from moisture from all sources. Carbon steels rust or oxidize rapidly in the presence of moisture, salt air, or industrial air pollution. The rust is formed from the solid metal, and gradually reduces the size and strength of the member with the passage of time. Uncoated steel members should be stored on cribbing under cover of a roof or tarpaulins to avoid such deterioration. Coated materials should be examined, and, if in good condition with no abraded or exposed areas, may be stored outdoors on cribbing.

Structural steel members are generally fabricated to precise designs for supporting specific loads in specific directions. Since most parts are prefabricated in shops for assembly and erection in the field, they are also fabricated precisely with respect to size and bolting-hole locations. Such members may be rendered unusable if bent, twisted or deformed from overstressing. Consequently, much care must be exercised in unloading and handling members; dropping or impact-loading members can result in kinks, misalignment and deformation.

STRUCTURAL STEEL ERECTION

Before actual erection work begins, all prefabricated members are checked against the applicable shop drawing. The following characteristics are examined, as applicable:

- member straightness, size and configuration
- surface preparation and coating
- milling of column ends
- bolt hole sizes, number, and layout
- finishing of sheared or flame-cut edges
- preparation of edges or surfaces to be welded

The erection site should also be inspected to verify that all preparations for the erection work have been completed. These preparations include the following:

- all required anchor bolts are located and installed correctly
- adequate bracing materials are on hand
- adequate tools and equipment are on hand
- proper fasteners are on hand, in adequate quantity

The erection of steel building skeletons or steel for other structural applications usually begins with the setting and bolting of columns (vertical members). Framing must be carried up true and plumb, and temporary bracing must be used whenever necessary to take care of all loads to which the structure may be subjected (wind, construction materials, erection equipment, etc). As erection progresses, the work is securely fastened to take care of all dead load, wind and erection stresses. No permanent fastening is done, however, until as much of the structure as will be stiffened thereby has been properly aligned and plumbed.

Some field connections are still made with hot-driven rivets. Before riveting, the members are aligned and matching holes brought into matching position with drift pins. Drift pins are tapered steel rods which are driven into one or more pairs of matching holes in two members, forcing the parts into position with respect to each other. The parts are held together rigidly while the rivets are driven with either compression or manually operated power riveters. After driving, the rivets must be tight with their heads in full contact with the steel surface. Drifting during assembly should not distort or enlarge holes. Holes that need to be enlarged to admit rivets or bolts are reamed to an acceptable size. After rivets have been driven into all open holes, the drift pins are removed and replaced with the final rivets. Hot-driven rivets are usually heated uniformly to a temperature approaching 1950°F, and are driven before their temperature falls below 1000°F.

Most contemporary structural designs require field connections to be made with high-strength bolts or by welding. Bolted members are aligned with drift pins, in the same manner as riveted connections. Members to be welded are usually aligned with welded clips and wedges. "Come-a-longs" (portable geared wrenches with steel cables) are generally used to assist in alignment and positioning, regardless of the method of connection.

High strength bolted members must fit solidly together when assembled and not be separated by gaskets or any other compressible materials. The surfaces of high strength bolted parts in contact with the bolt head and nut must not have a slope of more than 1:20 with respect to a plane normal to the bolt axis. Beveled washers must be used to compensate for any lack of parallelism exceeding this value.

High strength bolts must be tightened to a bolt tension not less than that shown in Table 29-2-6. Tightening must be done precisely with the turn-of-nut method, or with properly calibrated wrenches.

TABLE 29-2-6. Tightening Tension Requirements for High Strength Bolts

Bolt Size, Inches	Minimum Bolt Tension,[1] Kips[2]	
	A325 Bolts	A490 Bolts
1/2	12	15
5/8	19	24
3/4	28	35
7/8	39	49
1	51	64
1 1/8	56	80
1 1/4	71	102
1 3/8	85	121
1 1/2	103	148
Over 1 1/2		0.7 x T.S.

[1] Equal to 70 percent of specified minimum tensile strengths of bolts, rounded off to the nearest kip.

[2] Kips: 1 Kip = 1,000 lbs. deadweight load.

When the turn-of-nut method is used to provide the bolt tension as specified in Table 29-2-6, sufficient bolts in the connection are first tightened to a "snug fit" condition to assure that the parts of the joint are brought into intimate contact with each other. Snug fit is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following the initial tightening, bolts are placed in any remaining holes in the connection and brought to "snug tightness". All bolts in the connection are then tightened additionally by the applicable amount of nut rotation specified in Table 29-2-7, with the tightening progressing systematically from the most rigid part of the joint to its free edges. During the tightening operation, either the bolt or the nut may be rotated, but the other part must remain stationary.

TABLE 29-2-7. Nut Rotation From Snug Tight Condition

Disposition of Outer Faces of Bolted Parts		
Both faces normal to bolt axis, or one face normal to axis and other face sloped nor more than 1:20 (bevel washer not used)		Both faces sloped not more than 1:20 from normal to bo axis (bevel washers not use
Bolt length[b] not exceeding 8 diameters or 8 inches	Bolt length[b] exceeding 8 diameters or 8 inches	For all length of bolts
1/2 turn	2/3 turn	3/4 turn

[a] Nut rotation is rotation relative to bolt regardless of the element (nut or bol being turned. Tolerance on rotation: 30° over or under. For coarse thread heavy hex structural bolts of all sizes and length and heavy hex semi-finished nuts

[b] Bolt length is measured from underside of head to extreme end of point.

When calibrated wrenches (power or manual) are used for bolt tensioning, their setting should be such as to induce a bolt tension 5% to 10% in excess of the value specified in Table 29-2-6. Each calibrated wrench used should be re-calibrated at least once each working day by tightening at least three representative bolts of each diameter being installed, in a device capable of indicating actual bolt tension. Power wrenches should be adjusted to stall or cut-out at the desired tension. When manual torque wrenches are used, the torque indication corresponding to the calibrating tension should be noted and used in the installation of all bolts of the tested lot.

The bolt-tightening procedures described herein are industry-accepted methods specified by the American Institute of Steel Construction (AISC) and published in the Manual of Steel Construction by that organization.

When structural steel work is designed with welded connections, welding work is usually specified to be performed in accordance with the American Welding Society (AWS) specification D.1.1, Structural Welding Code. The welding processes used and the code requirements are the subject of other courses* and are not covered in this Module.

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* Nuclear Technology, Course 28, Welding Inspection

INSPECTION OPERATIONS

General

In most structural steel installation/erection projects, little or no testing is done. Testing is normally performed by the material manufacturers, who provide test reports of chemical and physical test results, or certificates of conformance to material specification requirements to the material purchasers upon request.

Inspection of the materials and the various erection operations by QA/QC technicians or inspectors, however, is usually performed, particularly on nuclear power plant projects.

Receiving Inspection

Inspection begins with the receipt inspection of materials at the job site before use. Materials such as rolled steel shapes, fabricated components, high-strength bolts, rivets and weld filler metal, are usually required to be examined for such characteristics as (1) proper identification, (2) correct size and grade, and (3) freedom from damage incurred in shipping and storage. When ordered to particular specification requirements, such as ASTM, the materials may be inspected for conformance to all applicable criteria. When materials are furnished with material test reports, the reported test results are compared with the applicable specification requirements to determine the acceptability of the materials. When found to be acceptable, the materials are released for construction use. When found to be unacceptable (nonconforming to specification requirements) the materials may be dispositioned in one of several ways: (1) rejected and removed from the job site, (2) rejected for the intended use, but approved for use (by the architect-engineer) in a different application where acceptable, or (3) re-evaluated (by the architect-engineer) and approved for use "as-is".

Receipt-inspection activities are fully documented. Reports include the following information.

- Date received
- Purchase order reference
- Specification requirements reference
- Quantities and description of material received
- Description of attributes examined & acceptance criteria
- Inspection results
- Accept/reject decision for each item examined

- Disposition of material (released for use, removed from job site, etc.)
- Signature of inspector and date inspected

Site Inspection

Before actual erection work begins, the erection site is inspected. Columns are usually the first members to be set and it is normally required that the column foundations be inspected for the following characteristics:

- Correct foundation location and size
- Concrete adequately cured
- Embedded anchor bolts: correct size, number, location and configuration; bolts free from rust, concrete spatter or thread damage.

As erection proceeds, columns are plumbed, temporarily braced, and bolted in place. The following items should be inspected:

- Column member identification (verify that correct part is being used)
- Correct orientation and alignment
- Proper anchor bolt tightness
- Column plumb, within tolerance
- Column elevation correct

When a sufficient number of columns have been set, inspected and approved to support subsequent erection work, cross members (beams, joints, etc.) and permanent brace members are installed. It is suggested that general surveillance inspection of these operations be performed during the erection and fastening work to verify the following:

- Correct members are installed at each specified location
- Member orientation and alignment is correct

- Correct fastening materials and methods are used:
  - Bolting - Correct size and type used. Washers used as required. Proper torquing method and value used. Bolts installed in all holes.
  - Rivets - Correct size and type used. Rivets driven to tight, full contact condition. Rivets installed in all holes.
  - Welding - Correct procedure used. Joint preparation acceptable. Correct filler metal (type and size) used. Welding technique and finished results acceptable. Welder qualified.
- Acceptable rigging and handling methods used, to preclude damage to structural members.

Final Inspection

On many projects, after the completion of bolt tightening operations, it is a requirement to inspect and verify that the tightening work is acceptable. This is done by applying the required torque, in the tightening direction and with a calibrated torque wrench, to 10% of the bolts, but not less than two bolts, selected at random in each connection. If no nut or bolt head is turned by this application of force, the connection is accepted as properly tightened. If any nut or bolt head is turned by the application of this force, this torque is applied to all bolts in the connection.

The final inspection of the erection work should include a random check of all of the aforementioned items and:

- Check final painting, coating and retouch work, as required by the job specifications.
- Check removal of all temporary bracing, scaffolding, safety nets, and contractor's materials and equipment from the area.
- Check completed condition of all connections.

Documentation

All inspections performed should be documented. Standard report forms are usually developed for each project, and may include check lists to guide the inspector in covering all required areas and operations. In general, the inspection reports should include:

- Identification of parts, joints, area, elevation, etc.
- Attributes or activities inspected
- Description of findings
- Specific accept/reject decisions
- Inspector's signature and date of inspection

Summary of Inspection

The following list summarizes the items that are typically checked or inspected during the various structural steel erection/installation operations:

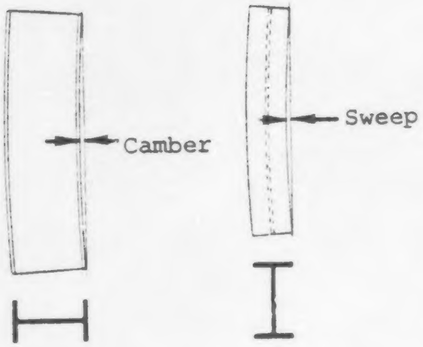
- Material grade and acceptability
- Prefabricated member shape, size and condition
- Shop-coating acceptable condition
- Bolt-hole lay-out and sizes
- Acceptable foundation preparations
- Contractor's steel materials handling and erection methods and equipment
- Plumbing and bolt tightening operations
- Field welding operations when applicable (weld filler materials, joint preparation, weld procedures, welder's qualifications and certifications)
- Calibration of bolt-tensioning equipment
- Inspection of finished bolted connections
- Documentation (material test reports, inspection reports, test reports, etc.)

A steel supplier has submitted test reports for samples of steel representing three lots of ASTM A36 steel shapes and three lots of ASTM A529 steel shapes. The values reported for the various required characteristics are shown below. Evaluate the reported values using Subject Matter of this module and circle all out-of-tolerance conditions.

ASTM A36 Steel Samples	Sample 1	Sample 2	Sample 3
Chemical Composition			
Carbon, %	0.252	0.238	0.271
Phosphorous, %	0.027	0.254	0.327
Sulfur, %	0.038	0.029	0.041
Physical Properties			
Tensile strength, psi	58,200	66,700	73,900
Yield point, psi	33,900	39,200	41,200
Elongation in 8 in.,%	18.9	22.7	23.2
Elongation in 2 in.,%	20.3	22.9	24.6

ASTM A529 Steel Samples	Sample 4	Sample 5	Sample 6
Chemical Composition			
Carbon, %	0.291	0.258	0.261
Manganese, %	0.073	1.021	1.319
Phosphorous, %	0.033	0.053	0.029
Sulfur, %	0.041	0.039	0.042
Physical Properties			
Tensile strength, psi	64,800	72,800	79,500
Yield point, psi	40,800	46,700	49,900
Elongation in 8 in., %	20.8	17.3	22.1

A group of 10 - 6" (nominal) "S" beams has been purchased to ASTM A6 straightness requirements. The applicable ASTM A6 requirements (for straightness) are shown below:



ASTM A6 Permissible Variations in Straightness for Beam
(S and M Shapes)

Variable	Nominal Size, in.	Permissible Variation, in.
Camber	under 3	1/4 in. in any 5 ft, or 1/4 x (number of feet of total length/5)
	3 and over	1/8 x (number of feet of total length/5)
Sweep	all	Due to the extreme variations in flexibility of these shapes, straightness tolerances for sweep are subject to negotiations between the manufacturer and the purchaser for the indiviual sections involved.

[a] Greatest cross-sectional dimension.

Positions for Measuring Camber and Sweep

The parts are identified by number and length, and inspected for straightness (camber). For each of the parts listed below, (a) calculate the permissible variation in camber, and (b) indicate accept/reject disposition of each part:

Part No.	Length, ft.	Measured Camber, in.	(a) Calculated Permissible Camber, in.	(b) Disposition Accept/Reject
1	10	3/16	_____	_____
2	15	1/2	_____	_____
3	15	1/4	_____	_____
4	20	11/16	_____	_____
5	25	9/16	_____	_____
6	35	5/8	_____	_____
7	30	13/16	_____	_____
8	20	5/8	_____	_____
9	20	7/16	_____	_____
10	5	3/32	_____	_____

EXERCISES

1. Tour a construction site involved with steel erection as indicated in the Procedures section of this module. Take notes on the Data Table 29-2-1 on page 29-2-24 as given in the Data Table section of this module.

2. List the basic structural members of roof support systems employing structural steel materials.

3. Discuss the methods of cutting steel parts and preparing bolt holes in structural steel members.

4. Explain the purpose of applying temporary protective coatings on structural steel members.

5. What are other methods of alignment used for erection of structural steel members?

6. Briefly discuss the use of drift pins in steel erection.

7. Describe the receipt-inspection operations including:
    a. basic examinations performed
    b. purpose of test reports
    c. acceptability of material test reports

8. What is meant by the "Turn-of-nut" method of bolt tensioning?

9. Discuss the final inspection of bolted fasteners including sample size and actions taken when acceptance criteria are not met.

MATERIALS

None.

PROCEDURES

1. Tour a construction site involved with steel erection. The tour should be guided by a construction supervisor knowledgeable of inspection activities. Take notes on Data Table 29-2-1.
2. Discuss in class notes of the construction site tour.

DATA TABLE

Data Table 29-2-1

Tour of Construction Site

Site: ______________________________

Construction Contractor: ______________________________

Inspection Agency: ______________________________

Bolting Operations:

  Bolt Identification ______________________________

  Nut Identification ______________________________

  Method of Alignment ______________________________

  Method of Torquing ______________________________

  Inspection ______________________________

Riveting Operations:

  Rivet Identification ______________________________

  Method of Alignment ______________________________

  Inspections ______________________________

Welding Operations:

  Joint Preparation ______________________________

  Welding Process ______________________________

  Inspections ______________________________

Material Storage:

  Description: ______________________________

REFERENCE MATERIALS

AISC, Manual of Steel Construction, American Institute of Steel Construction

Parker, Harry & Hauf, Harold D., Simplified Design of Structural Steel, Wiley-Interscience

AISC, Quality Criteria and Inspection Standards, American Institute of Steel Construction

Marcus, Samuel H., Basics of Structural Steel Design, Reston

TEST

1. List the basic structural components of roof support systems:
   a.
   b.

2. Name two methods of cutting parts from steel plate material:
   a. ____________________________
   b. ____________________________

3. State the purpose of reaming of punched or drilled holes in steel connections.

4. State the purpose of coatings applied to steel members.

5. Describe storage conditions at the job site for:
   a. Uncoated prefabricated steel members

   b. Coated prefabricated steel members

6. Describe the use of drift pins in steel erection.

7. State the typical temperature limits for rivet hot-driving operations.

8. State the purpose of bevel washers for bolted connections.

9. Describe the turn-of-nut method of bolt tensioning.

10. Name the specification which governs structural welding work.

11. State the three basic examinations performed during receipt inspection of materials.

12. State the purpose of material test reports and briefly describe how the acceptability of such reports is determined.

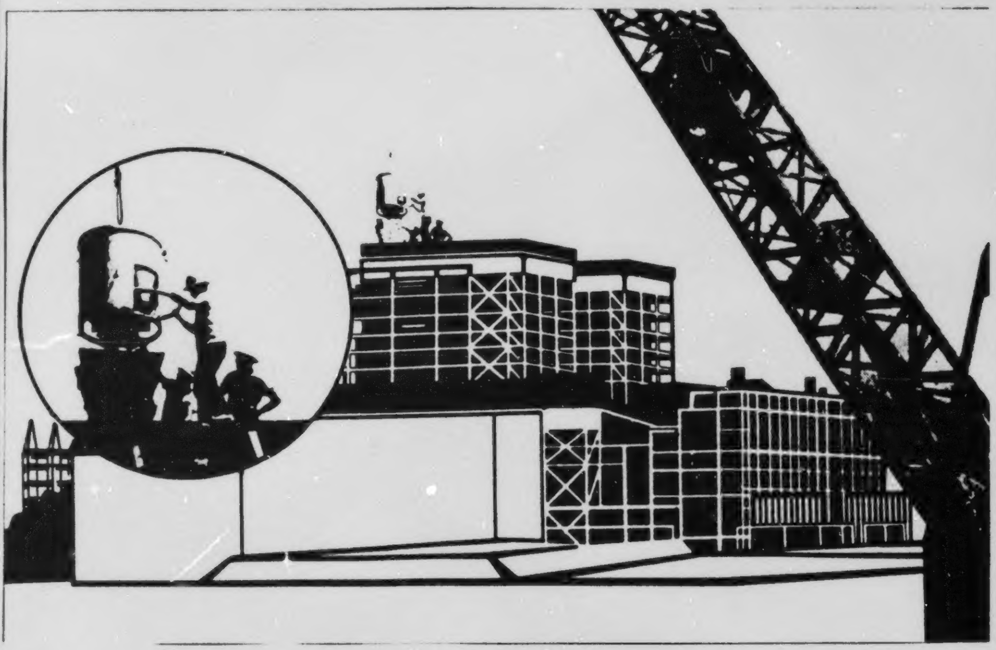
13. If a bolted steel connection contains sixteen bolts, how many bolts are tested for tightness.

14. If one of the bolts turns when testing bolted connections for tightness, what steps are taken?

NUCLEAR TECHNOLOGY

MODULE 29-3

CONCRETE MATERIALS



COURSE 29 CIVIL/STRUCTURAL INSPECTION

CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
4800 LAKEWOOD DRIVE WACO, TEXAS

COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

MODULE 29-1	Inspection of Construction Operations
MODULE 29-2	Structural Steel Materials, Installation and Inspection
⇨ MODULE 29-3	Concrete Materials
MODULE 29-4	Concrete Preparation, Production, Placement and Finishing
MODULE 29-5	Concrete Testing and Inspection
MODULE 29-6	Prestressed Concrete Materials, Fabrication and Inspection

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INTRODUCTION

Concrete is one of the most important and widely used construction materials. In its plastic, unhardened state, it can be handled and transported in many ways, such as by trucks, conveyors, pumps and various types of buckets. In its hardened state, it attains strength and durability which are dependent upon such factors as the type, quality and uniformity of component materials, the proportions of component materials, the thoroughness with which they are combined, and the transportation, placement and curing of the concrete.

This module deals with concrete component materials and discusses their properties, methods of handling and storage, selection, uniformity and methods of acceptance.

The information presented in this module reflects general construction practices and is designed to acquaint the trainee with the concrete materials used in the construction of nuclear and fossil power generating plants and similar heavy construction projects.

Supplemental information and reference materials may be obtained from the following sources:

American Concrete Institute (ACI)
American Society for Testing and Materials (ASTM)
National Ready Mixed Concrete Association (NRMCA)
Concrete Reinforcing Steel Institute (CRSI)

MODULE PREREQUISITES

The student/trainee should have prior training or experience on inspections of construction operations. Completion of Nuclear Technology, Module 29-1, satisfies this prerequisite.

OBJECTIVES

Upon completion of this module, the student/trainee can:

1. Identify the three basic components of concrete and describe typical characteristics of each.
2. Associate types of cement with the major characteristics of each type.
3. Describe proper handling and storage practices for cements, aggregates, admixtures, and reinforcing steels.
4. Describe the effect on concrete strength by variations in water quantity, cement quality and aggregate quality.
5. Generally describe the measurement of sizes of aggregates including "fineness modulus."
6. Describe the function of reinforcing steel and its identity marking scheme.
7. Name at least two chemical reactions which aggregate may cause and describe the results in terms of concrete quality.
8. Determine receptability of cements, aggregates, and reinforcing steel when given test results and material specification requirements.

SUBJECT MATTER

COMPONENT MATERIALS OF CONCRETE

Concrete is a mixture of cement, aggregates, water, and sometimes additives or admixtures which impart special characteristics to the concrete such as to accelerate set, retard set, improve workability or reduce the mixing water requirement. Concrete also contains some amount of entrapped air, and may contain purposely entrained air, which produces a more plastic mixture which is easier to place, and more resistant to freezing and thawing.

The selection of concrete proportions involves a balance between economy and requirements for strength and placeability. In general, the mixture consists of one part of cement, 1 1/2 to 2 1/2 parts of fine aggregate (such as sand), 3 to 5 parts of coarse aggregate (such as gravel or crushed stone), and clean water.

Concrete is strong in compression and shear but weak in tension. Compressive strength varies from about 2,000 to 6,000 lbs. per square inch, depending on the proportions. The mixture is plastic and, under normal conditions, will set up firm in a few hours (known as initial set) and attain full rated strength in about 28 days or less.

Reinforced concrete is concrete in which steel, usually in the form of deformed bars or welded wire mesh, is embedded so that the two materials act together in resisting forces. The combination uses the best properties of each material, namely the crush resistance or compressive strength of the concrete, and the pull resistance or tensile strength of the steel. The adhesion of the concrete to the surface of the bars, plus the resistance provided by the bar deformations or lugs, keeps the bars from slipping through the concrete. This gripping of the bars by the concrete is known as bond and makes the two materials act as one.

The selection of the component materials of concrete is made on the basis of availability, cost and characteristics which are required for the particular mix. The following describes the different types of materials and their characteristics.

Cements

The strength of any concrete mixture is directly related to the strength-producing properties of the cement used. The cements most used in the construction industry are portland cements, Types I, II and III. These cements are generally used as follows:

Type I:	Used in general concrete construction where the special properties specified for the other types are not required.
Type II:	Used in general concrete construction where moderate sulfate resistance or moderate heat of hydration is required.
Type III:	Used where high early strength is required.

Other portland cements not generally on the market are produced on order for special purposes:

Type IV:	Used when a low heat of hydration is required.
Type V:	Used when high sulfate resistance is required.

Portland cement is a hydraulic cement (i.e., a cemetitious material which reacts with water and hardens) produced by proportioning and mixing lime, alumina and silica; burning the mixture to form clinkers; and pulverizing the clinker to form the cement.

Air-entraining portland cements are produced to increase the amount of air held by the mortar or concrete made from the cement. These cements contain small amounts of air-entraining chemicals which are incorporated by intergrinding them with the clinker during manufacture. The additional air held in the resulting concrete improves the workability of the concrete and increases the resistance to freezing and thawing. The strength of air-entrained concrete, however, is usually less than that obtained with untreated cement. Air-entraining portland cements are produced in three of the types listed above, and are designated with the suffix "A", e.g., Type IA, Type IIA and Type IIIA.

Two blended cements have also been standardized by the industry and are available in areas where the materials are available economically. These cements are portland blast furnace slag cement, Type IS, and portland pozzolan cement, Type IP. For each of these there is a corresponding air entraining cement, Type ISA or Type IPA.

Portland blast furnace slag cement consists of a mixture of portland cement clinker and a proportion of 25-65 percent blast furnace slag material.

Portland pozzolan cement consists of an interground mixture of portland cement clinker and a proportion of 15-20 percent fine pozzolan material. The pozzolanic material used is a siliceous or aluminous material in the form of fly-ash, volcanic ash, or heat-treated diatomaceous earth.

The strength characteristics of the portland blast furnace slag cement are essentially the same as for regular portland cements, but the portland pozzolan cements produce significantly lower strengths.

Table 29-3-1 summarizes the minimum compressive strength requirements for the different portland and blended cements, as adopted by the construction industry. It should be noted that the air-entraining cements in all categories have significantly lower strength requirements than for the companion non-air-entraining types.

Table 29-3-1. Minimum Compressive Strength Requirements of Mortar for Different Portland and Blended Cements

Type of Cement	ASTM Specification Designation	Compressive Strength of 2 in Cubes, psi			
		1 day	3 days	7 days	28 days
		Non-air-entraining			
I	C 150	----	1200	2100	3500
II	C 150	----	1000	1800	3500
III	C 150	1700	3000	----	----
IV	C 150	----	----	800	1500
V	C 150	----	----	1500	3000
IS	C 205	----	1200	2100	3500
IS(M)	C 205	----	1000	1800	3500
IP	C 340	----	----	1500	3000
		Air-entraining			
IA	C 175	----	900	1500	2800
IIA	C 175	----	750	1400	2800
IIIA	C 175	1300	2500	----	----
ISA	C 205	----	900	1500	2800
ISA(MS)	C 205	----	750	1400	2800
IPA	C 340	----	----	1250	2500

Aggregates

Aggregates, known as mineral aggregates, constitute about 70 to 80 percent of the concrete mixture. Conventional aggregates include sand, gravel, crushed stone and blast furnace slag. In addition to these, a variety of lightweight aggregates are used for some applications.

Aggregates are inert filler materials used to make the concrete or mortar more economical and to minimize the shrinkage which is characteristic of most cements.

The principal characteristics considered in selecting aggregates are soundness and durability, hardness and strength, deleterious substances, and size and grading. Soundness and durability rank first among these, especially for concrete exposed to weather. If the aggregate particles disintegrate, the concrete disintegrates.

Aggregates generally are divided into two classes, coarse aggregates and fine aggregates. Coarse aggregate is usually gravel or crushed stone and fine aggregate is usually sand; when sand is not available, fine aggregate is made by crushing rock. Crushed, air-cooled blast furnace slag is sometimes used for fine or coarse aggregate. Lightweight aggregates include cinders and coke "breeze" or residue.

Hardness and strength are important characteristics of coarse aggregates, while grading, soundness and freedom from impurities are particularly important for fine aggregates. The fine particles in the concrete mixture separate the coarse particles and fill the voids between them, minimizing the amount of cement required and yielding a workable mixture.

Aggregate quality is frequently rated by resistance to abrasion, in addition to hardness and strength. Small and large coarse aggregates are tested for this quality with the Los Angeles Abrasion Test (ASTM C131 and ASTM C535). Test results are reported as percentage of wear (or percentage of material abraded away).

Deleterious substances in aggregates usually include clay lumps, coated particles, shale, coal, alkalies, laminated pieces, clay and silt, and organic matter. Concrete strength and durability are affected if these materials are present in any appreciable quantity in the aggregate material.

Aggregates, then, should consist of clean, hard, strong and durable particles which are not coated with dust, clay, silt, or other substances. Aggregates are screened to obtain the desired gradings and washed to remove objectionable impurities.

The sizes of coarse aggregates selected usually depend upon the character of the work. As a rule-of-thumb, the size should not exceed one-fifth the width or thickness of the member in which it is being placed, or three-fourths the clear space between reinforcing bars. A maximum size of 3" for use in any case is frequently specified.

Fine aggregates are generally considered to be all those which pass a sieve with 1/4" square openings. The ASTM standard C125 defines fine aggregate as aggregate (1) passing the 3/8 in. (9.5 mm) sieve and almost entirely passing the No. 4 (4.75 mm) sieve and predominantly retained on the No. 200 (75 µm) sieve, or (2) that portion passing the No. 4 (4.75 mm) sieve and retained on the No. 200 (75 µm) sieve.

The amount of fines, or small particles, in the fine aggregate is a significant factor in proportioning concrete. Samples of fine aggregates are tested by sifting through a series of specified, progressively smaller sieves, and measuring the amounts of material retained on each sieve. An empirical factor, the fineness modulus, is obtained by adding the total percentages of the sample aggregate retained on the sieves and dividing the total by 100. Typical specifications for fine aggregates require that the fineness modulus be within the limits of 2.3 to 3.1.

Water

The water used in concrete or mortar should be clean and practically free from acids, alkalies, salts and organic substances. Excessive quantities of any of these materials may adversely affect the time and rate of set and strength development. Water that is fit to drink may generally be regarded as acceptable for use in mixing concrete.

Admixtures

Admixtures are materials other than water, aggregates, and cement that are used as ingredients of concrete and are added to each batch immediately before or during its mixing, to impart special properties to the concrete.

Admixtures commonly used include chemical additives; pozzolans such as fly ash and volcanic ash; minerals such as ground quartz, limestone, or talc; coloring agents or pigments; fungicidal, germicidal, or pesticidal agents; dampproofing agents; permeability-reducing agents; and corrosion-inhibiting agents.

Certain chemical admixtures have been classified by ASTM and are defined in terms of function in standard C494 as follows:

Type A - water-reducing admixtures
Type B - retarding admixtures
Type C - accelerating admixtures
Type D - water-reducing and retarding admixtures
Type E - water-reducing and accelerating admixtures

Calcium chloride is a widely used admixture for accelerating set and obtaining high early strength. It is frequently used in cold weather concreting operations.

Many materials are capable of functioning as air-entraining admixtures and are used to enhance resistance to frost action, workability and watertightness of concrete. Some of the materials used are: (1) salts of wood resins, (2) some synthetic detergents, (3) salts of sulfonated lignin, (4) salts of petroleum acids, (5) salts of proteinaceous materials, (6) fatty and resinous acids and their salts, and (7) organic salts of sulfonated hydrocarbons.

Admixtures of finely divided minerals or pozzolans can be used to produce a variety of effects in concrete. These materials can be used to increase workability of the concrete without an increase in water content, to increase strength, and to reduce permeability. The properties of the specific admixture must be evaluated with the characteristics of the concrete mixture in which it is to be used, however, because some combinations of these materials produce a degradation of desired qualities.

Reinforcing Steel

Concrete has a low tensile strength and must be reinforced for most structural applications. The usual types of reinforcement are steel rods or bars, and welded wire fabric.

The standard type of reinforcing steel bar is the deformed bar. Each steel mill which rolls deformed bars may have a different pattern of deformation on the bar, but all are rolled to conform to ASTM specifications. Some of the types of deformation patterns are shown in Figure 29-3-1.

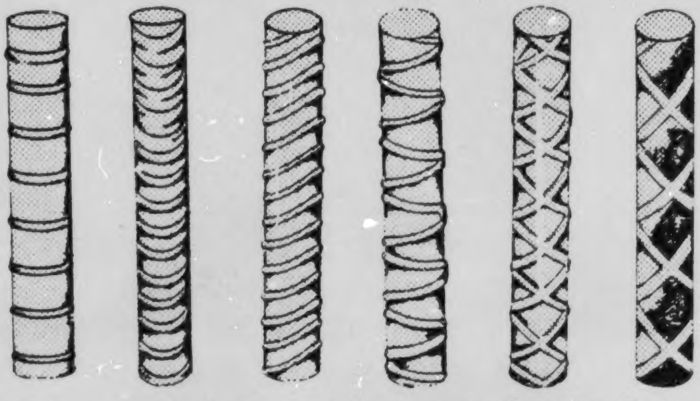


Figure 29-3-1. Types of Deformed Bars

Plain bars are smooth, round bars without deformations on them. Plain bars are not generally used for reinforcing, but for special purposes such as sliding dowels at expansion joints.

Reinforcing bars are manufactured in several grades which are described in ASTM standard specifications, marked and color coded before shipping. The "grade" designations of the bars refer to the minimum yield strength (nominal rating) of the steel. The most commonly used materials are as follows:

(1) ASTM A615 Billet Steel Bars for Concrete Reinforcement

Grade 40	(40,000 psi min. yield strength)
Grade 60	(60,000 psi min. yield strength)
Grade 75	(75,000 psi min. yield strength)

(2) ASTM A616 Rail Steel Bars for Concrete Reinforcement

Grade 50

Grade 60

(3) ASTM A617 Axle Steel Bars for Concrete Reinforcement

Grade 40

Grade 60

Deformed bars are available in eleven standard sizes, designated by numbers. The number denotes approximately the diameter of the bar in eighths of inches. For example, a #4 bar has an approximate diameter of 4/8 or 1/2 inch. The standard bars, which are defined by size and weight in the applicable ASTM specifications, are listed in Table 29-3-2.

Table 29-3-2

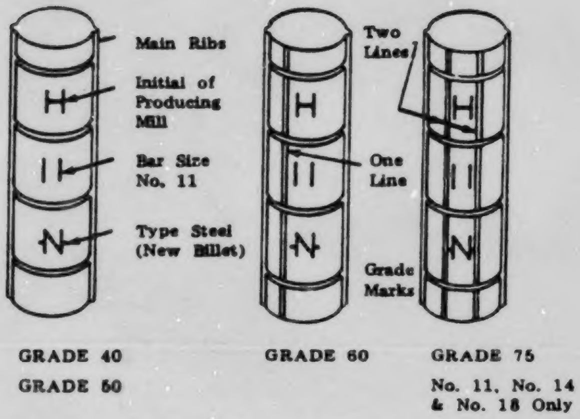
ASTM STANDARD REINFORCING BARS				
BAR SIZE DESIGNATION	WEIGHT POUNDS PER FOOT	NOMINAL DIMENSIONS—ROUND SECTIONS		
		DIAMETER INCHES	CROSS SEC-TIONAL AREA SQ. INCHES	PERIMETER INCHES
#3	.376	.375	.11	1.178
#4	.668	.500	.20	1.571
#5	1.043	.625	.31	1.963
#6	1.502	.750	.44	2.356
#7	2.044	.875	.60	2.749
#8	2.670	1.000	.79	3.142
#9	3.400	1.128	1.00	3.544
#10	4.303	1.270	1.27	3.990
#11	5.313	1.410	1.56	4.430
#14	7.65	1.693	2.25	5.32
#18	13.60	2.257	4.00	7.09

Different sizes and grades of bars are frequently used on the same construction site, and a means of identification is therefore important. ASTM specifications require that each bar producer roll the following identification marking on each bar.

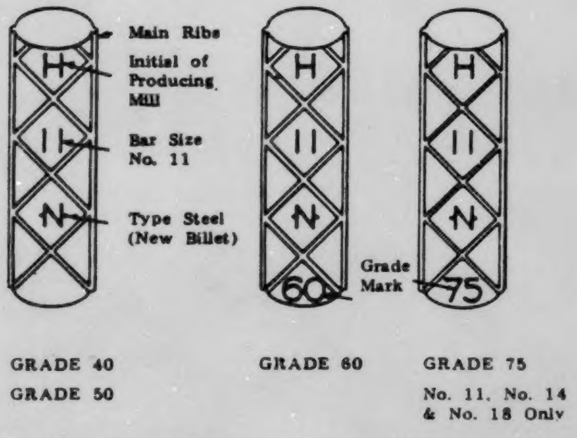
(1) mill symbol or letter
(2) number corresponding to bar size
(3) type of steel
(4) grade designation

Two bar marking systems which are used by producers are illustrated in Figure 2.

Welded wire fabric reinforcing consists of cold-drawn logitudinal or carrying wires, and usually smaller transverse wires or ties. The two sets of wires are connected at the intersections by welds. Various combinations of wire sizes and spacings are available with longitudinal spacing from 2 in. to 6 in., and transverse spacing from 8 in. to 16 in.


Main Ribs
Initial of Producing Mill
Bar Size No. 11
Type Steel (New Billet)
Two Lines
One Line
Grade Marks
H
11
N
GRADE 40
GRADE 50
GRADE 60
GRADE 75
No. 11, No. 14 & No. 18 Only

Continuous longitudinal smaller lines between the main longitudinal ribs. One small line identifies Grade 60, two such lines, Grade 75.


Main Ribs
Initial of Producing Mill
Bar Size No. 11
Type Steel (New Billet)
Grade Mark
H
11
N
60
75
GRADE 40
GRADE 50
GRADE 60
GRADE 75
No. 11, No. 14 & No. 18 Only

Rolled-on numbers follow the symbols and number that indicate bar size. The number "60" identifies Grade 60; the number "75", Grade 75.

Figure 29-3-2. Deformed Bar Marking Systems

MATERIALS HANDLING AND STORAGE

The consistent production of uniform, quality concrete requires proper handling and storage of the component materials. The following describes the practices generally employed in the construction industry related to these materials.

Cements

Cements may be purchased in loose, bulk quantities, or individual sacks. Regardless of the quantity, all cement should be stored in weathertight, properly ventilated structures to prevent the absorption of moisture.

Bulk cement is transported in truck tankers or railroad tank cars to the storage facilities at the concrete batch plant or the construction site where the material is usually unloaded with air pressure. The storage vessels, called cement silos, are covered cylindrical tanks with sloped bottoms usually equipped with air diffuser flow pads through which small quantities of low pressure air may be introduced intermittently to loosen settled cement. The silos may be divided into two or more compartments to provide segregated storage for different types of cement. Each compartment from which cement is batched normally includes a separate gate and a conveyance such as a screw conveyor, air slide, or rotary feeder to provide constant flow and precise cut-off characteristics for accurate batching and weighing.

Sacked cement may be transported by truck or rail, and should be stored in a sheltered area on pallets or platforms to permit circulation of air and avoid contact with ground or floor dampness.

Aggregates

Fine and coarse aggregates delivered to the concrete batcher must be of good quality and uniform in grading and moisture content.

Coarse aggregates are usually separated into several size fractions and batched separately to minimize segregation. Segregation is the separation of different sizes of materials within a mixture (e.g., the settling out of fines in a stock pile of coarse aggregate material).

Fine aggregates (sand) should be controlled to minimize variations in grading and to keep finer fractions uniform.

Improper handling and stockpiling methods cause segregation, breakage and contamination. The following suggested practices should be followed to minimize these effects:

(1) Stockpiling should be done on a hard base with with adequate drainage, preferably concrete, to prevent contamination from underlying material.

(2) Aggregates should not be dumped onto a sloped surface and allowed to run down and segregate.

(3) Trucks, bulldozers or other vehicular or track equipment should not be operated on the stockpiles because they may (a) break or crush the aggregate or (b) track dirt or other contaminants onto the piles.

(4) Stockpiles should not be contaminated by swinging aggregate filled buckets or clams over various stockpiled aggregate sizes.

(5) Intermixing of stockpiled materials should be prevented by the use of walls or ample spacing between piles.

Admixtures

Chemical admixtures in liquid form should be stored in watertight drums or tanks and protected from freezing. Chemical admixtures supplied in solid form are usually converted to liquid for dispensing into the concrete batcher.

These should then be stored in similar closed vessels which are equipped with agitation or mixing equipment to keep the solids in suspension and also protected from freezing.

Pozzolans and other dry additives should be handled and stored in the same manner as cement. Proper storage is particularly important to provide protection from dampness and contamination and to minimize lumping and warehouse set. Since the appearance of finely divided mineral admixtures is quite often similar to that of portland cement, storage and handling equipment should be clearly identified and marked and precautions taken to assure that leakage between storage compartments or carry-over contamination does not occur.

Reinforcing Steel

Reinforcing steel materials are generally delivered to the construction site on flatbed trucks or rail cars. Bundles of bars may be hoisted or skidded to the ground onto wood timbers to keep them free from mud and to provide for easy rehandling.

Straight bars are usually grouped by sizes and by lengths within a size so that easy identification is possible. Bent bars are similarly stockpiled and the tags of both straight and bent bars are kept at the same end for easy identification. When a bundle is opened and some of the bars are removed, the bar with the tag should remain with the bundle. (Normally only one bar in each bundle is tagged.) Hoists such as truck cranes, tower cranes and stiff-leg derricks are used to bundle reinforcing steel. When hoisting bundles of bars thirty feet or longer, it is necessary to use a spreader bar as illustrated in Figure 29-3-3 so that the bars will not bend excessively.

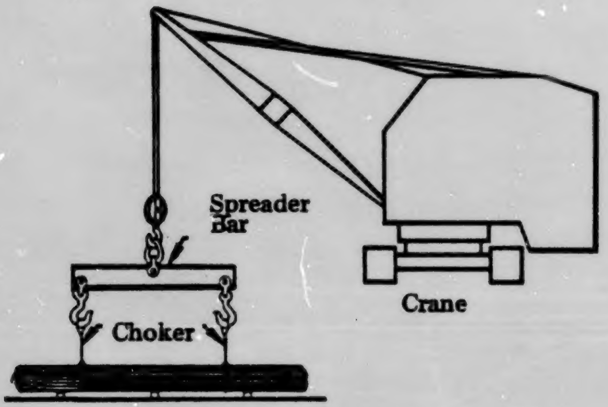

Spreader
Bar
Choker
Crane

Figure 29-3-3. Use of Spreader Bar

The spreader bar should be at least one-half the length of the bars in the bundle and may be fabricated from a piece of heavy pipe or an I-beam.

For bundles of bars under thirty feet in length, a bridle/choker rig, as illustrated in Figure 29-3-4 is most commonly used.

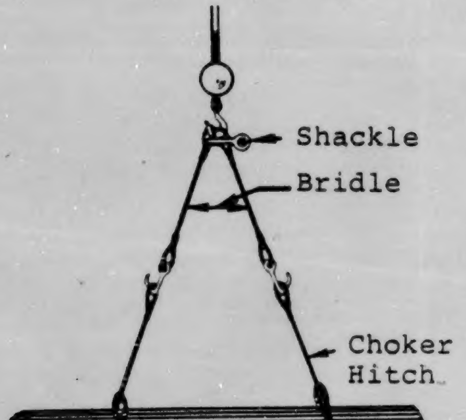

Shackle
Bridle
Choker
Hitch

Figure 29-3-4. Use of Bridle/Choker Rig

CONCRETE MATERIALS SELECTION

For any particular job, the concrete to be used must be "designed" to produce certain characteristics. The component materials and their proportions are selected to produce these desired characteristics which include strength, durability, workability, and optimum cost. It should be noted that these criteria conflict with each other: a concrete mix of maximum strength is not necessarily the most durable or workable and certainly not the least expensive. Acceptable levels, then, for each criterion must be established, and the "design mix" established accordingly.

Cement manufacturers or suppliers in any particular area will usually recommend design mixes to fit the users' requirements and the aggregate materials available. If it is to be used for a large construction project, the user generally has concrete samples of the mix made and physically tested to verify the acceptability of the design mix. If the test results indicate that the design mix is acceptable and as economical as possible, it will be used for production. If the samples fail to meet any of the requirements, adjustments will be made in the design mix and new samples made and tested.

MATERIALS UNIFORMITY

Experience and analysis of concrete component materials are used to develop design mixes and to predict strength, durability, workability and cost. Any variability or lack of uniformity of the component materials, however, will be reflected and first detected in the strength of the concrete.

On large construction projects, such as nuclear power plants, during concreting operations, mixed concrete is sampled, formed into test cylinders, and destructively tested to measure strength characteristics. Test results are recorded and plotted and any degradation in quality is easily recognized.

Concrete derives its strength from the hardness and compressive strength of the aggregate particles and the strength of the hardened cement paste binder. The strength of the cement binder is dependent on the amount of water and admixtures which have been used. The remainder of this section describes the effects on concrete strength of variations in cement, water, aggregates and admixtures.

Cement

Cement reacts with water and hardens. The amount of water that is used in any concrete mixture is known as the water-cement ratio, and is expressed as a "weight ratio" or as "gallons of water per sack of cement" (cement content is expressed as sacks of cement per cubic yard of concrete). To obtain plastic mixtures which will coat all of the particles and pieces of aggregate, more water must be used than can be combined chemically with the cement. The excess water will eventually evaporate from the hardened mass and leave voids which tend to reduce watertightness and strength of the concrete. No more water should be used than is necessary for the required chemical action and plasticity.

Any variations in the physical or chemical properties of the cement used will produce variations in the strength, durability and set-time of the concrete produced. Most cement used on construction projects is manufactured to standard specification, such as ASTM C150 for portland cement. When requested in the purchase order, the cement manufacturer will certify to the purchaser that the material supplied meets the requirements of the specification invoked. The user may accept the manufacturer's certification or take samples of the cement and have tests performed to verify the acceptability of the material. Different cements of the same type meeting the specification requirements usually produce uniform concrete mixtures which have similar qualities with only minor (acceptable) variations.

Aggregates

Mineral aggregates constitute about 70 to 80 percent of the typical concrete mixture and, consequently, their uniformity and quality characteristics are reflected directly in the concrete in which they are used. Aggregates may be purchased in accordance with a standard specification, such as ASTM C33. This specification defines the requirements for both fine and coarse aggregates, and provides limits for size grading, deleterious substances, soundness and physical properties. Variations in any of these categories will alter the water requirements of the concrete mixture which will change the water-cement ratio and alter the concrete durability and strength.

Aggregates may be encountered at times with different chemical compositions which are susceptible to harmful chemical reactions. Such reactions may result in abnormal expansion, cracking or loss of strength of the concrete. The three most common types of reactions are the (1) alkali-aggregate reaction, (2) the cement-aggregate reaction, and (3) the carbonate aggregate reaction.

The alkali-aggregate reaction occurs when alkalies (Na_2O and K_2O) from the cement react with siliceous constituents which are sometimes present in the aggregates. Aggregates with these properties have generally been found in the western half of the United States.

The cement-aggregate reaction is a chemical phenomenon occurring with certain sand-gravel aggregates found in Kansas, Nebraska and Wyoming, but the reaction is not caused by the alkali content of the cement. The phenomenon can be identified, but the mechanism involved in the concrete deterioration has not been specifically determined.

Aggregates in some areas of Canada, Iowa and Indiana which contain approximately equal amounts of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) have exhibited reactivity with cement alkalies, which is known as the carbonate aggregate reaction. This reaction has also produced aggregate expansion and consequent cracking of the concrete.

For large projects, it is advisable to sample all aggregate materials in advance and to perform laboratory tests for potential chemical reactivity, to preclude possible concrete deterioration from these causes. There are no known methods of adequately preserving existing concrete which contains the elements that contribute to the previously described chemical reactions.

Many other properties of concrete are also influenced by aggregate properties. Table 29-3-3 summarizes many specific concrete properties and the relevant, or influencing, aggregate characteristics.

Table 29-3-3. Properties of Concrete Influenced by Aggregate Properties

Concrete Property	Relevant Aggregate Property
Durability:	
Resistance to freezing and thawing	Soundness Porosity Pore structure Permeability Degree of saturation Tensile strength Texture and structure Presence of clay
Resistance to wetting and drying	Pore structure Modulus of elesticity
Resistance to heating and cooling	Coefficient of thermal expansion
Abrasion Resistance	Hardness
Alkali-aggregate reaction	Presence of particular siliceous constituents
Strength	Strength Surface texture Cleanness Particle shape Maximum size
Shrinkage	Modulus of elasticity Particle shape Grading Cleanness Maximum size Presence of clay
Coefficient of thermal expansion	Coefficient of thermal expansion Modulus of elasticity
Thermal conductivity	Thermal conductivity
Specific heat	Specific heat
Unit weight	Specific gravity Particle shape Grading Maximum size

Table 29-3-3 (cont'd). Properties of Concrete Influenced by Aggregate Properties

Concrete Property	Relevant Aggregate Property
Modulus of elasticity	Modulus of elasticity Poisson's ratio
Slipperiness	Tendency to polish
Economy	Particle shape Grading Maximum size Amount of processing required Availability

Admixtures

Admixtures are used to modify or improve certain properties of concrete. Typically, relatively small quantities of admixture materials are used in the concrete batch (only a small amount is required to produce the desired effect). Variations, then, in either the admixture material or the quantity used may produce a significant variation in the resulting concrete. Every precaution must be taken to assure uniformity of the materials and extreme accuracy in their measurement.

Water

The water content, or water-cement ratio, of the concrete mixture is the most important factor to concrete strength and durability. In general, potable water, or water suitable for drinking, is suitable for concrete mixing. Precise control of the water content must be maintained during concrete batching, including precise compensation for the moisture contained in the aggregate materials.

Figure 29-3-5 illustrates the effect of the water-cement ratio on 2 typical samples of concrete (air-entrained and non-air-entrained). As the water-cement ratio in the air-entrained concrete specimen increases from 0.40 to 0.60, the compressive strength at 28 days decreases from 4800 psi to 2700 psi, or a 44% loss in strength. As the water-cement ratio in the non-air-entrained specimen increases from 0.40 to 0.60, the compressive strength at 28 days decreases from 5800 psi to 3700 psi, or a 36% loss in strength. This illustrates how over-utilization of water to make the concrete mixture more fluid for convenience in the field can drastically lower its ultimate strength.

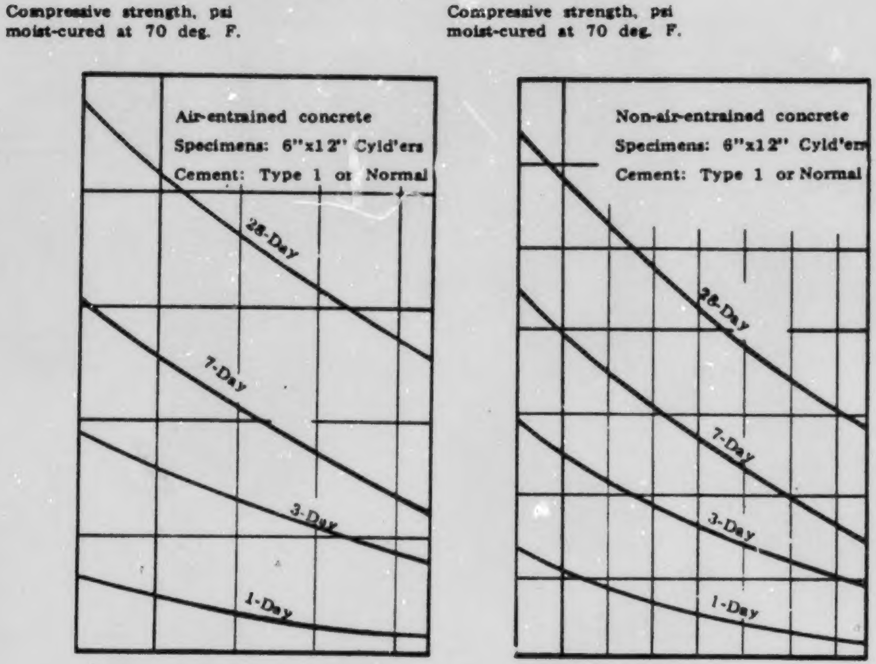


Figure 29-3-5. Effect of Water-Cement Ratio Variations Concrete Strength

MATERIALS ACCEPTANCE

The quality and uniformity of concrete can only be controlled when consistently uniform, acceptable component materials are used. It is important that specifications be established for all component materials, and that the materials supplied be monitored and periodically tested to verify conformance to the specification requirements.

The standard specifications generally accepted and used by the construction industry are those developed and published by the ASTM.

Typical Material Standards

Portland Cement

Portland cements are manufactured in accordance with ASTM standard C150. When purchasing portland cements, it is recommended that this specification and the cement type (I, II, III, etc.) be included in the purchase specification. The purchaser may also request a manufacturer's certification that the material was tested in accordance with the C150 specification, together with a report of the actual test results.

The standard chemical and physical requirements as specified in ASTM C150 are listed in Tables 29-3-4 and 29-3-5.

Table 29-3-4. ASTM C150 Standard Chemical Requirements for Portland Cement

Cement Type	I and IA	II and IIIA	III and IIIA	IV	V
Silicon dioxide (SiO_2), min, percent	----	21.0	----	----	----
Aluminum oxide (Al_2O_3), max, percent	----	6.0	----	----	----
Ferric oxide (Fe_2O_3), max, percent	----	6.0	----	6.5	----
Magnesium oxide (MgO), max, percent	5.0	5.0	5.0	5.0	5.0
Sulfur trioxide (SO_3),[a] max, percent					
When ($3\ CaO \cdot Al_2O_3$)[a] is 8 percent or less	3.0	3.0	3.5	2.3	2.3
When ($3\ CaO \cdot Al_2O_3$)[a] is more than 8 percent	3.5	b	4.5	b	b
Loss on ignition, max, percent	3.0	3.0	3.0	2.5	3.0
Insoluble residue, max, percent	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate ($3\ CaO \cdot SiO_2$)[a] max, percent	----	----	----	35	----
Dicalcium silicate ($2\ CaO \cdot SiO_2$)[a] min, percent	----	----	----	40	----
Tricalcium aluminate ($3\ CaO \cdot Al_2O_3$)[a] max, percent	----	8	15	7	5
Tetracalcium aluminoferrite plus twice the tricalcium aluminate[a] ($4\ CaO \cdot Al_2O_3 \cdot Fe_2O_3 + 2(3\ CaO \cdot Al_2O_3)$), or solid solution ($4\ CaO \cdot Al_2O_3 \cdot Fe_2O_3 + 2\ CaO \cdot Fe_2O_3$), as applicable, max, percent	----	----	----	----	20.0

[a] The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

Tricalcium silicate = (4.071 x percent CaO) - (7.600 x percent SiO_2) - (6.718 x percent Al_2O_3) - 1.430 x percent Fe_2O_3) - (2.852 x percent SO_3

Dicalcium silicate = (2.867 x percent SiO_2) - (9.7544 x percent C_3S)

Tricalcium aluminate = (2.650 x percent Al_2O_3) - (1.692 x percent Fe_2O_3)

Tetracalcium aluminoferrite = 3.043 x percent Fe_2O_3

When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as ss (($C_4AlFe + C_3Al$)) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

ss ($C_4AlFe + C_3Al$) = (2.100 x percent Al_2O_3) + (1.702 x percent Fe_2O_3)

Tricalcium silicate = (4.071 percent CaO) - (7.600 x percent SiO_2) - (4.479 x percent Al_2O_3) - (2.859 x percent Fe_2O_3) - (2.852 x percent SO_3)

No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown.

Table 29-3-4 (cont'd). ASTM C150 Standard Chemical Requirements for Portland Cement

In the calculation of C_3Al, the values of Al_2O_3 determined to nearest 0.01 percent shall be used. In the calculation of other compounds the oxides determined to the nearest 0.1 percent shall be used.

Values for C_3Al and for the sum of $C_4AlFe + C_3Al$ shall be reported to the nearest 0.1 percent. for other compounds shall be reported to the nearest 1 percent.

[b]Not applicable.

Table 29-3-5. ASTM C150 Standard Physical Requirements for Portland Cement

Cement Type	I	IA	II	IIA	III	IIIA	IV	V
Air content of mortar,[a] volume percent:								
max	12	22	12	22	12	22	12	12
min		16		16		16		
Fineness, specific surface, cm²/g (alternative methods):[b]								
Turbidimeter test, min	1600	1600	1600	1600			1600	1600
Air permeability test, min	2800	2800	2800	2800			2800	2800
Soundness								
Autoclave expansion, max, percent	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Strength, not less than the values shown for the ages indicated below:[c]								
Compressive strength, psi (MPa)								
1 day					1800 (12.4)	1450 (10.0)		
3 days	1800 (12.4)	1450 (10.0)	1500 (10.3) 1000[e] (6.9)[e]	1200 (8.3) 800[e] (5.5)[e]	3500 (24.1)	2800 (19.3)		
7 days	2800 (19.3)	2250 (15.5)	2500 (17.2) 1700[e] (11.7)[e]	2000 (13.8) 1350[e] (9.4)[e]			1000 (6.9)	2200 (15.2)
28 days							2500 (15.5)	3000 (20.7)
Time of setting (alternative methods):[d]								
Gillmore test:								
Initial set, min, not less than	60		60	60	60	60	60	60
Final set, h, not more than	10		10	10	10	10	10	10
Vicat test:								
Initial set, min, not less than	45		45	45	45	45	45	45
Final set, h, not more than	8		8	8	8	8	8	8

able 29-3-5 (cont'd). ASTM C150 Standard Physical Requirements for Portland Cement

[a] Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.

[b] Either of the two alternative fineness methods may be used at the option of the testing laboratory. However, in case of dispute, or when the sample fails to meet the requirements of the air-permeability test, the turbidimeter test shall be used, and the requirements in this table for the turbidimetric method shall govern.

[c] The strength at any age shall be higher than the strength at any preceding age.

[d] The purchaser should specify the type of setting-time test required. In case he does not so specify, or in case of dispute, the requirements of the Vicat test only shall govern.

[e] When the optional heat of hydration or the chemical limit on the sum of the ricalcium silicate and tricalcium aluminate is specified.

Cement users usually do not perform chemical or physical tests on material received. Normally, for large projects, the manufacturer tests and certifies each batch of cement that is shipped. Occasionally, samples may be taken for verification by an independent laboratory, but the manufacturer's reports are usually used as a basis for accepting the material.

Aggregates

Specifications based on tests and past service records may be developed and used for specific aggregate materials available in local areas, or standard specifications such as those published by the ASTM may be used when the specification is appropriate for the material available.

ASTM C33, Standard Specifications for Concrete Aggregates is a typical standard used in the construction industry and provides standards for Fine Aggregate and for Coarse Aggregate. Some of the requirements listed in ASTM C33 are as follows:

Fine Aggregate

Fine aggregate shall be graded in accordance with the sieve analysis limits listed in the specification and shall have a fineness modulus of not less than 2.3 or more than 3.1.

Deleterious substances shall not exceed the limits prescribed in Table 29-3-6.

Table 29-3-6. Limits for Deleterious Substances in Fine Aggregate for Concrete

Item	Weight Percent of Total Sample, max
Clay lumps and friable particles	3.0
Material finer than 75-μm (No. 200) sieve:	
Concrete subject to abrasion	3.0[a]
All other concrete	5.0[a]
Coal and lignite:	
Where surface appearance of concrete is of importance	0.5
All other concrete	1.0

[a] In the case of manufactured sand, if the material finer than the 75-μm (No. 200) sieve consists of the dust of fracture, essentially free from clay or shale, these limits may be increased to 5 and 7%, respectively.

Other requirements for fine aggregate covered in the specification include: variation in fineness modulus, organiz impurities and soundness.

Coarse Aggregate

Coarse aggregates shall be graded between the limits specified and shall conform to the requirements prescribed in Table 29-3-7.

The specification (C33) defines "weathering regions" in the U.S.A. and designates classes of concrete construction as a basis for coarse aggregate requirements. The weathering regions are illustrated on the map in Figure 29-3-6. The class designation, 1 through 5 are listed in Table 29-3-8 along with limits for deleterious substances and physical properties.

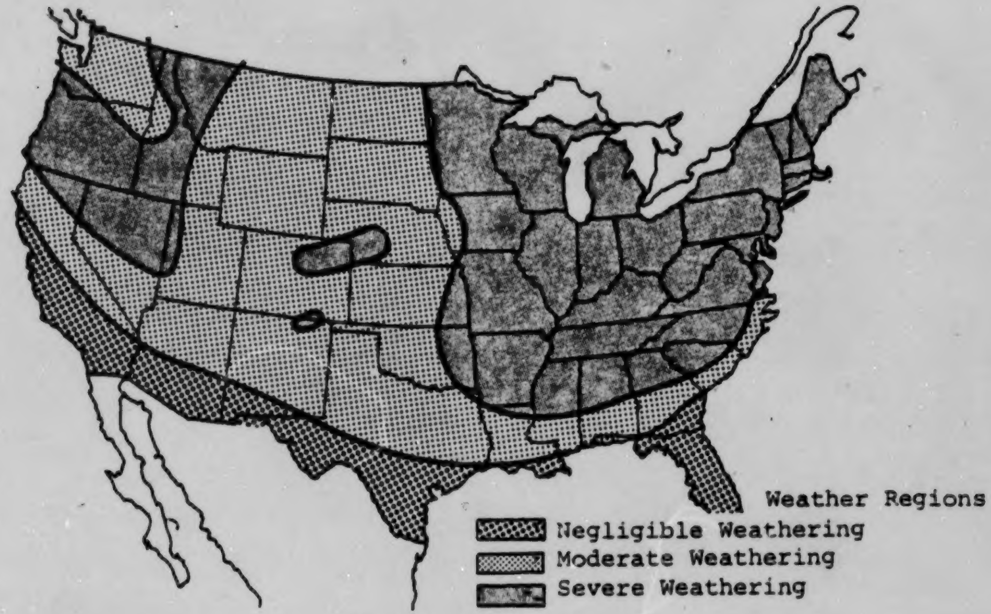
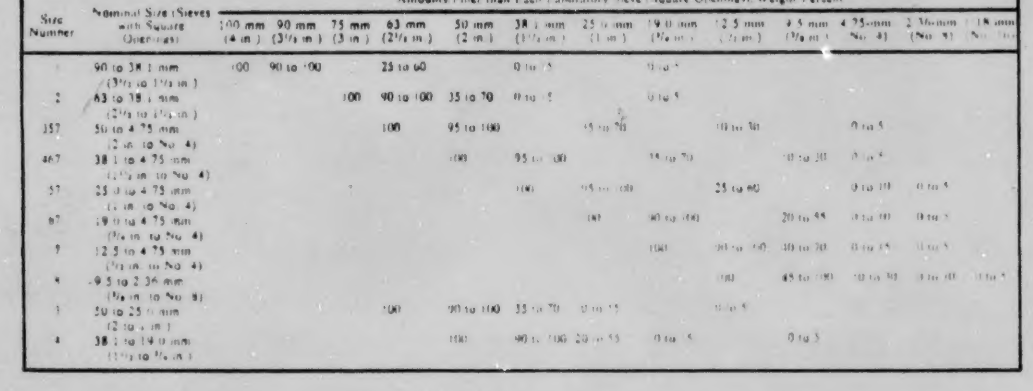


Figure 29-3-6
Concrete Weathering Regions in the USA

Table 29-3-7. Grading Requirements for
for Coarse Aggregates



Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square Openings), Weight Percent												
		100 mm (4 in.)	90 mm (3½ in.)	75 mm (3 in.)	63 mm (2½ in.)	50 mm (2 in.)	38.1 mm (1½ in.)	25.0 mm (1 in.)	19.0 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75-mm (No. 4)	2.36-mm (No. 8)	1.18 mm (No. 16)
1	90 to 38.1 mm (3½ to 1½ in.)	100	90 to 100		25 to 60		0 to 15		0 to 5					
2	63 to 38.1 mm (2½ to 1½ in.)			100	90 to 100	35 to 70	0 to 15		0 to 5					
357	50 to 4.75 mm (2 in. to No. 4)				100	95 to 100		35 to 70		10 to 30		0 to 5		
467	38.1 to 4.75 mm (1½ in. to No. 4)					100	95 to 100		35 to 70		10 to 30	0 to 5		
57	25.0 to 4.75 mm (1 in. to No. 4)						100	95 to 100		25 to 60		0 to 10	0 to 5	
67	19.0 to 4.75 mm (¾ in. to No. 4)							100	90 to 100		20 to 55	0 to 10	0 to 5	
7	12.5 to 4.75 mm (½ in. to No. 4)								100	90 to 100	40 to 70	0 to 15	0 to 5	
8	9.5 to 2.36 mm (⅜ in. to No. 8)									100	85 to 100	10 to 30	0 to 10	0 to 5
3	50 to 25.0 mm (2 to 1 in.)				100	90 to 100	35 to 70	0 to 15		0 to 5				
4	38.1 to 19.0 mm (1½ to ¾ in.)					100	90 to 100	20 to 55	0 to 15		0 to 5			

9-3-8. Class Designations, Limits for Deleterious Substances, and Physical Property Requirements of Coarse Aggregate for Concrete

Class Designation*	Type or Location of Concrete Construction	Maximum Allowable, %						
		Clay Lumps and Friable Particles	Chert (Less Than 2.40 sp gr SSD)^c	Sum of Clay Lumps, Friable Particles and Chert (Less Than 2.40 sp gr SSD)^c	Material Finer Than 75-µm (No. 200) Sieve	Coal and Lignite	Abrasion^a	Magnesium Sulfate Soundness (5-cycles)^b
		Severe Weathering Regions						
1S	Footings, foundations, columns and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	---	----	1.0^d	1.0	50	--
2S	Interior floors without coverings	5.0	---	----	1.0^d	0.5	50	--
3S	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	5.0	5.0	1.0^d	0.5	50	18
4S	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures, subject to frequent wetting	3.0	5.0	5.0	1.0^d	0.5	50	18
5S	Exposed architectural con-concrete	2.0	3.0	3.0	1.0^d	0.5	50	18
		Moderate Weathering Regions						
1M	Footings, foundations, columns and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	---	----	1.0^d	1.0	50	--

Table 29-1-8 (Cont'd). Class Designations, Limits for Deleterious Substances, and Physical Propert
Requirements of Coarse Aggregate for Concrete

Class Designation	Type or Location of Concrete Construction	Clay Lumps and Friable Particles	Chert (Less Than 2.40 sp gr SSD)[c]	Sum of Clay Lumps, Friable Particles and Chert (Less Than 2.40 sp gr SSD)[c]	Material Finer Than 75-μm (No. 200) Sieve	Coal and Lignite	Abrasion[a]	Magnesium Sulfate Soundness (5-cycles)[b]
2M	Interior floors without coverings	5.0	---	----	1.0[d]	0.5	50	--
3M	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather[e]	5.0	8.0	10.0	1.0[d]	0.5	50	18
4M	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures subject to frequent wetting[e]	5.0	5.0	7.0	1.0[d]	0.5	50	18
5M	Exposed architectural concrete[e]	3.0	3.0	5.0	1.0[d]	0.5	50	18
		Negligible Weathering Regions						
1N	Slabs subject to traffic abrasion, bridge decks, floors, sidewalks, pavements[e]	5.0	---	----	1.0[d]	0.5	50	--
2N	All other classes of concrete[e]	10.0	000	----	1.0[d]	1.0	50	--

[a] Crushed air-cooled blast-furnace slag is excluded from the abrasion requirements. The compact unit weight of crushed air-cooled blast furnace slag shall be not less than 70 lb/ft^3 (1120 kg/m^3). The grading of slag used in the unit weight test shall conform to the grading to be used in the concrete. Abrasion loss of gravel, crushed gravel, or crushed stone shall be determined on the test size or sizes most nearly corresponding to the grading or gradings to be used in the concrete. When more than one grading is to be used the limit on abrasion less shall apply to each.

e 29-3-8 (cont'd). Class Designations, Limits for Deleterious Substances, and Physical Property Requirements of Coarse Aggregate for Concrete

[b] The allowable limits for soundness shall be 12% if sodium sulfate is used.

[c] These limitations apply only to aggregates in which chert appears as an impurity. They are not applicable to gravels that are predominantly chert. Limitations on soundness of such aggregates must be based on service records in the environment in which they are used.

[d] In the case of crushed aggregates, if the material finer than the 75-μm (No. 200) sieve consists of the dust of fracture, essentially free of clay or shale, this percentage may be increased to 1.5. A greater amount of dust of fracture passing the 75-μm sieve may be permitted provided the amount passing the 75-μm sieve in the fine aggregate is less than the specified maximu. In such case, the sum of the amounts finer than the 75-μm sieve from the separate fine and coarse aggregates shall not exceed the sum of the weighted maximum amounts permitted for the coarse plus fine aggregate.

[e] For construction at altitudes exceeding 5000 ft. above sea level, the requirements of the "Severe Weathering Region" shall apply.

* Suffix letters indicate weathering condition; S - Severe, M - Moderate, and N - Negligible.

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Aggregate users usually either perform tests on the purchased materials, or have tests performed by a testing laboratory to verify the suitability and acceptability of materials received. Some of the tests frequently performed are as follows:

Particle size distribution (grading, gradation, sieve analysis)

Reference specification: ASTM C136

Particle size distribution has an effect on all the properties of concrete related to water requirement. The sieve analysis is probably the most frequently made of all aggregate tests. The particle size distribution is determined directly by passing samples of the aggregate through a nest of sieves of successively smaller openings and weighing the material retained on each sieve.

Specific gravity

Reference specifications: Coarse aggregate, ASTM C127;
Fine aggregate, ASTM C128

An accurate knowledge of the specific gravity of both fine and coarse aggregate is required to calculate the batch weights of materials to be used.

Unit weight

Reference specification: ASTM C29

The dry, rodded unit weight, together with the specific gravity, provides a means for computing the voids in a unit volume of aggregate. In mixture proportioning, it provides a basis for estimating the amount of cement required for a given coarse aggregate.

Absorption

Reference specification: ASTM C127, C128

Aggregate absorption is determined directly from the weights of a sample in the saturated surface-dry and over-dry conditions, and is required for determining surface moisture on samples of the same material by the oven drying method.

Surface moisture

Reference specification: ASTM C127, C128

A knowledge of surface moisture is essential for proportioning and controlling mixing water. Water carried into the concrete mixer on the aggregate must be subtracted from the weight of water added while the quantity of aggregate must be increased by an equal amount. Surface moisture is commonly determined by oven drying a sample and subtracting from the total water content the amount of absorbed water.

Admixtures

The specifications which are most widely used and cover those types or classes that make up the bulk of current production admixtures are listed in Table 29-3-9.

Table 29-3-9. Specifications for Concrete Admixtures

ASTM D 98	Calcium Chloride
ASTM C 260	Air-Entraining Admixtures
AASHO M 154	Air-Entraining Admixtures
CRD-C 13	Air-Entraining Admixtures
ASTM C 618	Fly Ash and Raw or Calcined Natural Pozzolans
Federal Specification SS-P-570b	Pozzolans
CRD-C 262	Pozzolan
ASTM C 494	Chemical Admixtures
CRD-C 87	Chemical Admixtures
USBR	Water-Reducing Set-Controlling Admixtures

A typical specification for air entraining admixtures is ASTM C260. This specification includes the following performance requirements:

(1) The bleeding of concrete made with the test admixture shall not exceed that of concrete made with a reference admixture by more than 2 percent.

(2) Both the initial and final times of setting of concrete containing the test admixture shall not deviate from that of the concrete made with a reference admixture by more than ± 1 hour and 15 minutes.

(3) The compressive strength at any test age of concrete containing the admixture under test shall be not less than 90 percent of that of similar concrete containing the reference admixture at the same test age.

Standard test methods are available to evaluate admixtures from the user's viewpoint. Some of these tests are listed in Table 29-3-10. Although such tests are valuable for selecting and accepting admixture products, any substantial use of continuously produced concrete should be preceded by testing that allows observation and measurement of the performance of the product under concrete plant operating conditions in combination with the concrete component materials then in use.

Admixtures are usually tested for acceptance for one or more of four reasons: (1) to determine compliance with the purchase specification, (2) to evaluate the effect of the admixture on the properties of the concrete to be made under the anticipated conditions, (3) to determine within lot uniformity, and (4) to provide data showing that any lot is the same as those previously supplied.

The specifications listed in Table 29-3-10 are typical of those in current use for testing various concrete admixtures.

Table 29-3-10. Admixture Testing Specifications

ASTM C233	Testing Air-Entraining Admixtures for Concrete
ASTM C441	Test for Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete due to the Alkali-Aggregate Reaction
ASTM C311	Sampling and Testing Fly Ash for Use as an Admixture in Portland Cement Concrete
ASTM C494	Chemical Admixtures for Concrete

Reinforcing Steel Bars

Deformed concrete reinforcing bars rolled from billet steel are produced to the requirements of ASTM A615 or A706. ASTM A615 is specified for most applications, and A706 for special applications requiring a combination of higher strength, weldability, ductility and improved bending properties.

Bars are available in two grades under ASTM A615 and one grade under ASTM A706. The required mechanical properties are listed in Table 29-3-11.

Table 29-3-11. Mechanical Properties of Hot Rolled Deformed Concrete Reinforcing Bars

	Tensile Strength, Min. PSI	Yield, Min. PSI
ASTM A615, Gr. 40	70,000*	40,000
ASTM A615, Gr. 60	90,000*	60,000
ASTM A706 (one grade)	80,000*	60,000

*Tensile strength shall not be less than 1.25 times the actual yield strength.

A bend test is required by ASTM A615 for bar sizes 3 to 11. ASTM A706 requires a bend test on all bar sizes. The pin diameters and degree of bend vary with the grade and bar size as designated in the two ASTM standards.

The chemical composition of the steel affects the mechanical properties. The extent to which certain elements are present is at the option of the reinforcing bar producer when producing for conformance to ASTM A615. The maximum cast or heat analysis for phosphorous in ASTM A615 is 0.05 percent. The composition limits of ASTM A706 are listed in Table 29-3-12 and the maximum carbon content must not exceed a specified value given in ASTM A706.

Table 29-3-12. Chemical Composition Limits for ASTM A706 Steel Bars

Element	Max. Percent
Carbon	0.03
Manganese	1.50
Phosphorous	0.035
Sulfur	0.045
Silicon	0.50

EXERCISES

1. **Portland Cement**

Samples of three shipments of Portland Cement are received for acceptance evaluation. Test report data for each sample is shown below. In accordance with the requirements shown in Tables 29-3-4 and 29-3-5 determine the disposition of each sample, and list the reasons for the accept/reject decisions:

Cement Sample: Type Cement:	A I	B II	C IV
SiO_2, %	not reported	23.7	not reported
Al_2O_3, %	not reported	4.81	not reported
Fe_2O_3, %	not reported	3.65	not reported
MgO, %	4.31	2.98	6.9
Loss on Ignition, %	1.75	2.15	3.1
Insoluble Residue, %	0.69	0.48	0.89
Air Content of Mortar, Vol. %	9.35	13.15	11.30
Compressive Strength 1 day, psi	not reported	not reported	not reported
3 days, psi	1875	1360	not reported
7 days, psi	2980	2310	1050
28 days	not reported	not reported	2580
Time of Setting Vicat Test: Initial Set, Min.	43	53	58
Final Set, Hr.	4.9	9.1	9.8

2. Fine Aggregates

The test data from test reports of representative samples of three fine aggregate shipments are shown below. Using the information provided in this text, determine the disposition of each sample, and list the reasons for the accept/reject decisions: (Note: the material will be used for back filled foundation concrete).

Aggregate Sample	A	B	C
Fineness Modulus	2.8	2.6	3.0
Clay lumps and friable particles, et. %	2.3	2.7	3.4
Material finer than 75-μm (No. 200) sieve, wt. %	3.4	4.5	4.1
Coal and Lignite, wt. %	0.7	0.6	1.7

3. Coarse Aggregates

The test data from test reports of representative samples of three coarse aggregate shipments are shown below. Using the information provided in this text, determine the disposition of each sample, and list the reasons for the accept/reject decisions: (Note: the material will be used for exposed floors and porches under moderate weathering conditions).

Aggregate Sample	A	B	C
Clay lumps and friable particles, %	3.7	4.2	5.9
Chert (less than 2.40 sp. gr.), %	2.1	2.4	6.8
Coal and lignite, %	1.3	0.2	0.6
Abrasion, %	21	37	39
$HgSO_4$ soundness ($NaSO_4$ used)	13.9	10.7	17.5

4. Reinforcing Steel Bars

The test data from test reports of representative samples of four lots of deformed bars are shown below. Using the information provided in this text determine the disposition of each lot, and list the reasons for the accept/reject decisions.

Sample	A	B	C	D
Type (ASTM)	A615	A615	A706	A615
Grade	60	40	--	60
Yield, psi	74,800	43,800	65,500	63,400
Tensile, psi	92,700	74,900	83,800	87,200

MATERIALS

The following materials are used to support this module:

1. Samples of various sizes and grades of rebar.
2. Samples of various aggregates and admixtures.

PROCEDURES

1. Visually inspect rebar for compliance with marking requirements.
2. Visually examine sample aggregates. Discuss importance of shape, range of sizes, and fines.
3. Tour a concrete supplier's facilities. Note practices in the following areas and discuss notes in class:
    a. storage of cements
    b. storage of aggregates
    c. water supply and quality
    d. batch definition
    e. batch weighing and mixing
    f. testing

DATA TABLE

None

REFERENCE MATERIALS

ACI Manual of Concrete Practice, American Concrete Institute, Detroit, Michigan

Materials, Design and Control of Quality Concrete, Protex Industries, Inc., Denver, Colorado

Control of Quality of Ready-Mixed Concrete, National Ready Mixed Concrete Association, Silver Spring, Maryland

Placing Reinforcing Bars, Concrete Reinforcing Steel Institute, Chicago, Illinois

Specifications for Ready-Mixed Concrete of the American Society of Testing and Materials, National Ready-Mixed Concrete Association, Silver Spring, Maryland

TEST

1. Complete the following statements:

   a. The three basic components of concrete are ______________, ______________ and ______________.

   b. Concrete is usually reinforced with ________________ ________________.

   c. ________________________________ is the commonly used material to bind concrete.

   d. The two general classes of aggregates are __________ and ________________.

   e. A measure of the fine particles in fine aggregate materials is generally reported as the ____________ _____________.

   f. Materials which are added to concrete mixtures to produce certain characteristics are called ____________________________________.

   g. The _________________ ______________ is the standard material used for reinforcing structural concrete.

   h. The full rated strength of concrete is usually attained in __________ days.

2. What type of cement would be recommended for each of the following specific desired characteristics:

   a. high sulfate resistance? ________________________

   b. general construction use? ________________________

   c. low heat of hydration? ________________________

   d. high early strength? ________________________

3. Type I and Type II air entrained cements would be identified as __________________ and _________________.

Underline and correct the errors in the following materials handling and storage procedures in Questions 4 through 7.

4. Cement
    a. Bulk cement to be delivered in dump trucks.
    b. Unload into bins by gravity flow.
    c. May be intermixed with old cement stock.
    d. Sacked cement to be stored in sheltered area on pallets.

5. Aggregates
    a. Materials to be stockpiled in earthen pit.
    b. Materials to be piled on flat surface.
    c. Stockpiled material may be intermixed to reduce batching time.
    d. Truck traffic over stockpiled material improves the material gradation.

6. Admixtures
    a. Chemical admixtures may be stored in open tanks, in all seasons.
    b. Pozzolan storage should be in dry, closed vessels.
    c. Finely divided mineral admixtures are similar in appearance to fine aggregates, and clear identification is required.

7. Reinforcing Steel
    a. Deformed bars are stored on the ground.
    b. Bundles of 40' bars may be hoisted easily with a choker in the center during erection operations.
    c. For handling bundles of short bars, a bridle/choker rig may be used.

8. Describe how a purchaser can determine the acceptability of cements purchased to ASTM C150.

9. Describe the effects on concrete quality of foreign substances in aggregates.

10. Describe the effects on concrete quality by an excessively high water-cement ratio.

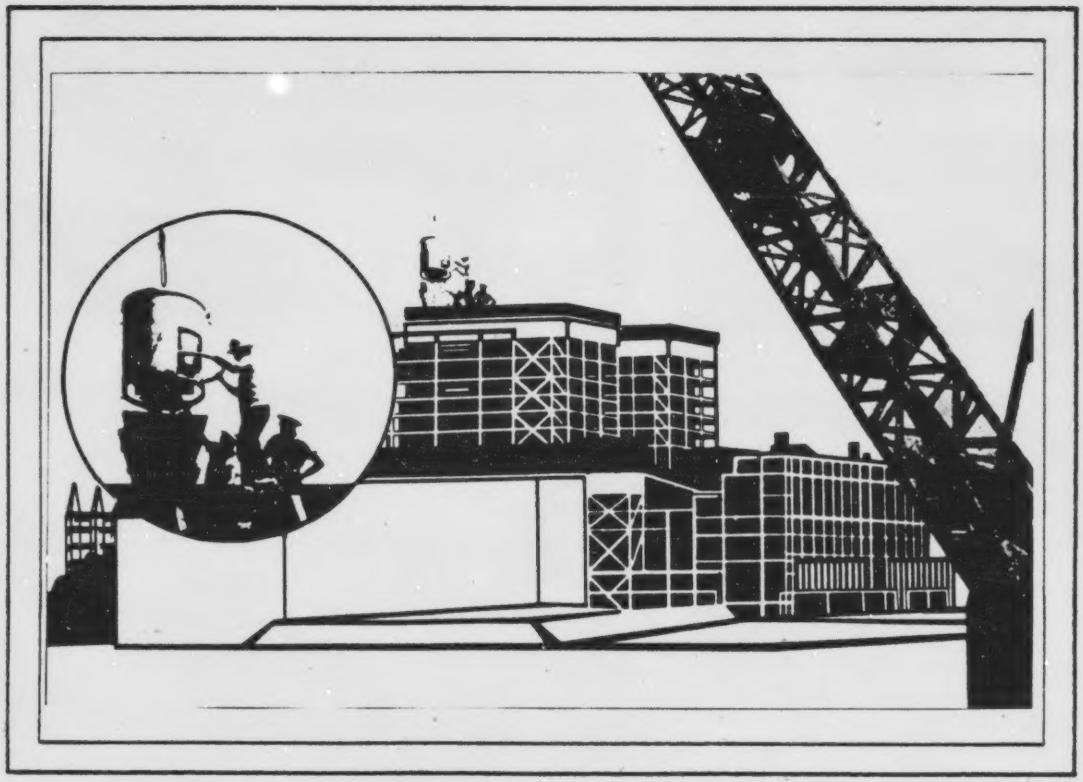
11. Describe the function of reinforcing steel including why it is deformed.

12. Name two chemical reactions which aggregates may cause and describe their effects on concrete quality.

NUCLEAR TECHNOLOGY

MODULE 29-4

CONCRETE PREPARATION CONCRETE PREPARATION, PRODUCTION, PLACEMENT, AND FINISHING



COURSE 29 CIVIL/STRUCTURAL INSPECTION

CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
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COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

MODULE 29-1	Inspection of Construction Operations
MODULE 29-2	Structural Steel Materials, Installation and Inspection
MODULE 29-3	Concrete Materials
⇨ MODULE 29-4	Concrete Preparation, Production, Placement and Finishing
MODULE 29-5	Concrete Testing and Inspection
MODULE 29-6	Prestressed Concrete Materials, Fabrication and Inspection

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INTRODUCTION

Vast quantities of concrete are required on construction projects such as the typical nuclear power plant. To meet the design requirements, the concrete must have the required strength, and be homogeneous, water-tight and resistant to weather. These properties can only be obtained through quality workmanship and adherence to the applicable codes, standards and specifications.

This module introduces some of the organizations which develop codes and standards for the construction industry, and lists the commonly used standards for structural concrete work.

Various types of concrete and their uses are described, along with the use of additives and special materials. Special techniques employed in hot weather and cold weather concreting operations are presented.

Equipment used in concrete production, such as for batching, mixing and transporting, is described, and various techniques of placement, consolidation and finishing are discussed.

Grouting operations are defined and described, and the use of construction joints and various finishing methods explained.

The QA/QC technician could easily be involved in any or all of these construction activities. Codes and specifications are used in generating purchase orders for materials, and in establishing acceptance criteria for receiving the materials. Standards and accepted-practice guides are used in developing work procedures, inspection procedures, and inspection check lists.

In functioning as a concrete inspector, the QA/QC technician would have to be familiar with all aspects of concrete production, placement and finishing methods and practices, and the methods of documenting and reporting the activities inspected and attendant test results. Various types of records are discussed, and typical concrete pre-placement, placement, and post-placement record forms are illustrated.

MODULE PREREQUISITES

The student/trainee should complete Modules 29-1 and 29-3 before proceeding with this module.

OBJECTIVES

Upon completion of this module, the student trainee should be able to perform the following:

1. Given a list of construction activities related to concreting operations, identify appropriate standards or recommended practice guides.
2. Complete a set of written exercises which demonstrate a knowledge of concrete production practices.
3. Given a set of written questions about concrete production equipment, select the correct answers.
4. Answer correctly a set of questions about various aspects of concrete placement and consolidation.
5. Given descriptions of typical grouting operations, answer pertinent written questions and calculate mix proportions.
6. Demonstrate a knowledge about construction joints, and concrete finishing and cleanup operations by answering correctly a set of written questions.

SUBJECT MATTER

CODES AND STANDARDS

ASTM

The ASTM, American Society for Testing and Materials, is a scientific and technical organization whose charter is to develop standards on characteristics and performance of materials, products, systems and services; and the promotion of related knowledge. It is the largest organization of its type in the world, and is composed of representatives from all fields, most of whom are recognized as technical experts in their fields.

Part 10 of the ASTM Annual Book of Standards is titled "Concrete and Mineral Aggregates". Part 10 includes many standards relating to concrete, cement, aggregates, curing materials, admixtures, and a manual of concrete testing. The following standards from Part 10 are used routinely for the production and control of concrete for projects such as nuclear power plants:

ASTM C33	Specification for Concrete Aggregates
ASTM C94	Specification for Ready-Mixed Concrete
ASTM C125	Definition of Terms Relating to Concrete and Concrete Aggregates
ASTM C143	Test for Slump of Portland Cement Concrete
ASTM C150	Specification for Portland Cement
ASTM C173	Test for Air Content of Freshly Mixed Concrete by the Volumetric Method

ACI

The ACI, American Concrete Institute, is a technical organization composed of members who are technical experts and represent concrete users and concrete producers.

The following standards are published individually as well as in Part 1 of the ACI Mnaual of Concrete Practice, and are frequently imposed for concreting operations in the construction of nuclear power plants:

ACI 211.1	(ANSI A167.1) Recommended Practice for Selecting Proportions for Normal Weight Concrete
ACI 212.1	(Title No. 68-56) Guide for Use of Admixtures in Concrete
ACI 212.33	(Title No. 60-64) Admixtures for Concrete
ACI 214.65	(ANSI 146.1) Recommended Practice for Evaluation of Compression Test Result of Field Concrete
ACI 221.1	(Title No. 58-24) Selection and Use of Aggregates for Concrete
ACI 304.73	Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete
ACI 304	(Title No. 68-33) Placing Concrete by Pumping Methods
ACI 305.72	Recommended Practice for Hot Weather Concreting
ACI 306.66	(ANSI A144.1) Recommended Practice for Cold Weather Concreting
ACI 308.71	Recommended Practice for Curing Concrete
ACI 309.72	Recommended Practice for Consolidation of Concrete
ACI 311.64	Recommended Practice for Concrete Inspection
ACI 347.68	(ANSI A145.1) Recommended Practice for Concrete Formwork

NRMCA

The NRMCA, National Ready Mixed Concrete Association, is an organization represented by concrete producers, which develops and publishes guides relative to the production, use, quality and acceptability of ready-mixed concrete.

Some of their frequently used publications are as follows:

Ready-Mixed Concrete Specifications and Their Administration
Standards for Operation of Truck Mixers and Agitators of the National Ready-Mixed Concrete Association
Cold Weather Ready-Mixed Concrete
Cooling Ready-Mixed Concrete
Sampling and Testing Ready-Mixed Concrete

CRSI

The CRSI, Concrete Reinforcing Steel Institute, is comprised of fabrication and producers of reinforcing steel. One of their most useful publications is Placing Reinforcing Bars which presents the best-accepted current practices in placing reinforcing bars, bar supports and welded wire fabric.

CONCRETE PRODUCTION

Concrete is formulated and batched differently for different applications. Concrete known as normal weight concrete is the general type most used in plant construction work, and usually has a weight denstiy of from 130 to 160 pounds per cubic foot. It is mixed with aggregates of normal density, as distinguished from lightweight or high density aggregates. Most normal weight concrete is proportioned to produce compressive strengths form 2,500 to 5,000 pounds per square foot, and may be formulated with admixtures to produce a variety of special characteristics, such as accelerated or retarded set, improved workability, increased strength, or reduction in mixing water. It is used for many applications, including foundations, slabs, walls and columns.

Structural lightweight concrete is concrete that, (1) is made with lightweight aggregates, (2) has a compressive strength in excess of 2,500 pounds per square inch when tested at 28 days, and (3) has a weight density (air dry weight) not in excess of 115 pounds per cubic foot. Structural lightweight concrete is used for two main purposes: (1) to reduce the weight of the structure, thereby reducing the required size of structural supporting members, or (2) to use as structural and/or thermal insulating or fill material.

When lightweight concrete is used for weight reduction properties alone, the aggregates listed in ASTM specification C 330, classed as Group II materials are to be used. These materials include blast furnace slag, shale, slate, fly ash, scoria and pumice. These materials typically produce concrete with a weight density of from 90 to 115 pounds per cubic foot, which is used for walls and slab construction.

When lightweight concrete is selected for thermal insulating properties, ASTM specification Group I materials, perlite or vermiculite, are used, or a combination of Group II and Group I materials are used. Group I materials can be used to produce insulating concrete with a weight density of from about 20 to 90 pounds per cubic foot, which may be used for floor fill, fire walls, fire protection, and roof construction. The range of unit weights normally obtained in concrete made from lightweight aggregates is shown in Figure 29-4-1.

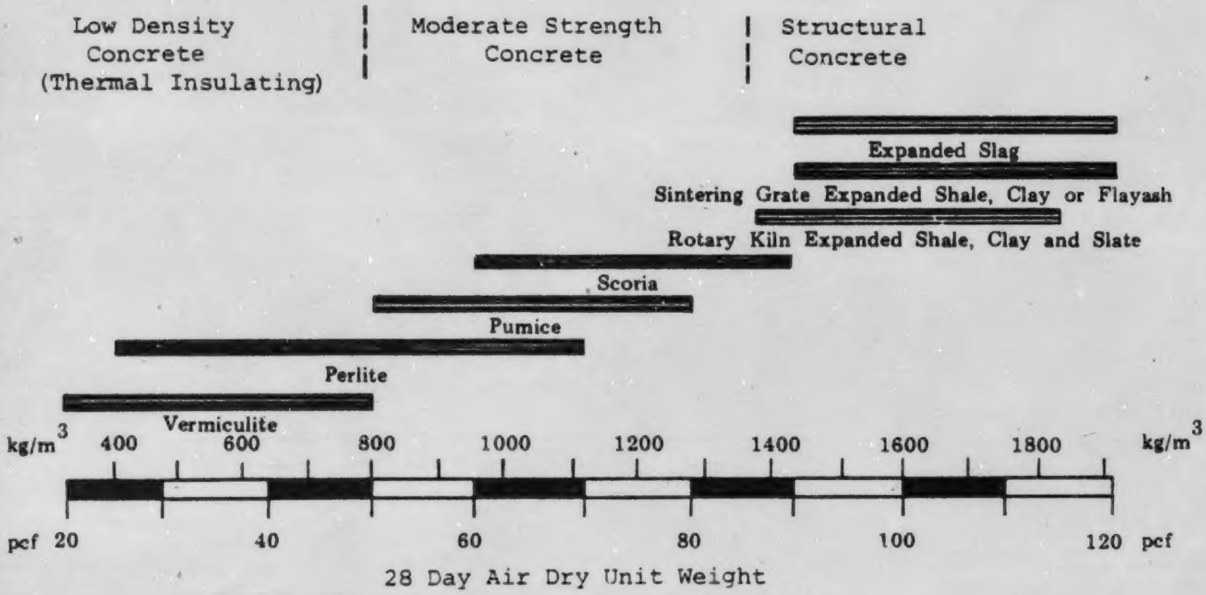


Figure 29-4-1. Lightweight Aggregate Concretes: Unit Weight and Uses Classification

Heavyweight aggregate concrete is high density concrete used primarily for radiation shielding. Aggregates such as bariet, magnetite, hematite and serpentine sometimes are used, and generally selected by the physical properties required. In cases where the weight density of the concrete is required to exceed 300 pounds per cubic foot, steel punchings or lead balls and lead shot may be used. Boron additions also may be used to increase the radiation absorption properties of concrete, but set-time and early strength development may be adversely affected.

Weather Conditions

Weather is an important factor in concrete production and placement. Different procedures and techniques are used for hot weather and for cold weather concreting.

As it affects concrete, hot weather is defined as any combination of high air temperature, low relative humidity, and wind velocity tending to impair the quality of fresh or hardened concrete. The effects of hot weather are most critical during periods of rising temperature, falling relative humidity, or both. The adverse effects are more serious on a dry, windy day than a calm, humid day at identical air temperatures. Some of the undesirable hot weather effects are:

- Rapid evaporation of mixing water
- Difficulties with normal handling, finishing and curing
- Difficulty in controlling entrained air
- Accelerated set
- Increased tendency to crack or craze
- Reduced strength
- Reduced bond of concrete to reinforcing steel
- Possible "cold" joints

PRODUCTION EQUIPMENT

The selection of a concrete batch plant is usually based on, (1) the size of the job, (2) the required production rate, and (3) the required standards of accuracy or batching standards. A plant consists of compartmented bins for storing cement and aggregate materials separately, scales for weighing the materials when they are batched, and storage and dispensing equipment for mixing water and for admixtures.

For jobs requiring batching rates up to about 25 cubic yards per hour, manual batch plants frequently are used. For larger jobs, however, semi-automatic or automatic batching equipment is used. With the more sophistocated equipment, devices such as automatic mix selectors, aggregate moisture meters and compensators, and recorders are used.

Regardless of the type of plant or equipment, the accurate measurement of total mixing water (added water, mixer wash water, ice, aggregate free moisture, etc.) is of paramount importance. All equipment for water measurement should be designed for easy calibration so that accuracy of measurement can be quickly verified.

An optimum temperature for concrete at time of placement is about 60°F; this usually cannot be attained in hot weather. A maximum of 90°F, however, is recommended by the ACI as an upper limit.

To minimize the temperature of the concrete, the ingredients should be kept as cool as possible. The temperature of the mixing water has the greatest effect of the constituents due to its higher specific heat, and, when used cold, will effect a moderate reduction in concrete placing temperatures. The use of ice as part of the mixing water is highly effective in reducing the temperature of the mix. It may be shaved or crushed and placed directly into the mixer as part or all of the required mixing water. Some additional cooling of the aggregates may be obtained from evaporation by keeping them moist prior to use. Retarders which reduce the rate of hardening and reduce the water requirements of the concrete may also be used to offset the increased water demand resulting from hot weather.

Special precautions and procedures are also required in cold weather to insure that adequate strength is attained before the concrete has an opportunity to freeze or is exposed to temperatures low enough to impair the strength development. At any time that frost may occur, or the mean daily temperature is below 40°F, cold weather protection is necessary. To preclude freezing until adequate protection can be established, the ACI recommends that the temperature of concrete as placed should be above the following values:

Very thin sections (approximate maximum size rock: 3/4"): 55°F
Thin sections (approximate maximum size rock: 1-½"): 50°F
Moderately massive sections (approximate maximum size rock: 3"): 45°F
Massive sections (approximate maximum size rock: 6"): 40°F

In areas where temperatures do not commonly fall below freezing, it is sufficient to heat the mixing water alone to achieve these concrete temperatures. In colder climates, it may be necessary to heat the aggregates also. This may be accomplished with open or closed steam coils in the aggregate storage bins, or with heated air blown through pipes under the stockpiles. For placing concrete when the air temperature ranges from about 0° to 30°F, an optimum mixed concrete temperature is from about 60°-70°F, with a "do-not-exceed" temperature of 90°F.

Accelerating admixtures, such as calcium chloride, may also be used to accelerate the set, hasten the hardening, and develop strength earlier. These materials will not prevent freezing, however; protection will still be required during curing.

Depending on the equipment used, concrete may be mixed in a central plant (central mixed concrete) and transported to the discharge point in agitating or non-agitating truck bodies, or mixed entirely in transit or after reaching the dishcarge point (transit mixed or truck mixed concrete) or mixed partially in a central plant and completed in transit (shrink mixed concrete).

Three types of mixers are commonly used: the drum, the vertical shaft, and the spiral blade. The drum mixer has a rotating drum with internal blades arranged to exchange the materials end-for-end, and roll, fold and spread the batch over itself. The vertical shaft mixer has revolving blades or vertical shafts operating in either a stationary pan or in a revolving pan, rotating in the opposite direction. The spiral blade mixer consists of a power driven horizontal shaft with spiral blades, operating in a horizontal drum. Visual observation of the concrete being mixed is an important aid in maintaining a uniform mix and uniform consistency.

The ultimate strength and durability of the concrete is dependent upon accurate batching, thorough mixing, homogeneity, and water content. These factors are affected and controlled by:

1. Batcher scale accuracy and calibration
2. Water meter/control accuracy and calibration
3. Batcher/hopper discharge gates/valves precision operation
4. Mixing operations:
    a. Mixing blades clean, with no excessive wear
    b. Mixing drums clean
    c. Mixers operated at proper speed
    d. Correct mixing time observed, number of revolutions
    e. Discharge from holding drum within allowed time
    f. Maximum allowed water addition observed

PREPARATIONS FOR CONCRETE PLACEMENT

Before concrete is placed, the forms should be thoroughly cleaned out to remove all trash and debris. In most cases, oiled forms are used, and need no further preparation. If un-treated forms are used, however, they should be sprinkled or hosed-down with water, to prevent the absorption of water by the forms from the concrete during placement and the early stages of curing.

An inspection should be conducted before placement to check proper form alignment, shoring and bracing, and proper installation of reinforcing steel and other embedded items.

If the concrete is to be placed directly on grade, rock surface or a previous concrete pour, the surface should be wet-down thoroughly with water and the excess allowed to drain off.

Finally, it should be verified that all equipment, materials and personnel are "ready to go" before concrete batching and placement begins.

Concrete Placement

Concrete is transported to the placing site and is discharged or transferred into other equipment for delivery to the forms. This equipment includes buckets, wheelbarrows, hoppers, manual or motor propelled "buggies" (carts), chutes and drop pipes, belt conveyors, pumping equipment, and tremies. Some of these devices will be illustrated later in this section.

Buckets and choppers are normally handled with a crane, and are equipped with manual discharge gates. They may be opened or closed easily during any portion of the discharge cycle.

Wheelbarrows and buggies require smooth, rigid runways and ramps to minimize vibration and prevent separation of concrete materials in transit.

Chutes and drop pipes are used for transferring concrete from upper to lower elevations. Chutes are sloped to permit the concrete to flow continuously down the chute without segregation. Drop pipes are located in a plumb position so that the concrete will drop vertically. When using long drop pipes, it is customary to have telephone communication between the top of the pipe and the placement area.

Portable conveyors are frequently used for short lift or reach placements. These machines cantilever the discharge point beyond the undercarriage wheels and can be elevated or lowered by self-contained units.

Stationary conveyors made up of a number of belt conveyors in series applications. The feeder belts used for such long reach placements operate at high speed to minimize the time concrete is exposed to adverse weather such as wind and hot sun.

Concrete is fed to conveyors through hoppers to obtain a uniform ribbon of material along the belt. The belts are well supported to obtain smooth, non-vibrating travel to minimize segregation.

Pumped concrete is concrete that is conveyed by pressures through either rigid pipe or flexible hose and discharged directly into the placing area. Pressure is applied by piston pumps, compressed air, or squeeze pressure. Concrete mixes for pumping must be plastic and well mixed. Particular attention should be given to the mortar (cement, sand and water) and to the amounts and sizes of coarse aggregates, as material uniformity is imperative for a successful pumping operation.

As important as the way concrete is batched, mixed and transported, is the way it is discharged into handling equipment and into forms. Concrete will separate seriously unless discharged and handled properly.

When filling hoppers, buckets or buggies, the concrete should be dropped vertically into the center of the receptacle, and not allowed to strike sloping sides. If this practice is not observed, separation will result.

When dropping concrete from a conveyor or chute, a "down pipe" should be used, as shown in Figure 29-4-2, to prevent separation. The "down pipe" should be used regardless of the length of the conveyor or chute, or whether the concrete is being discharged into hoppers, buckets, cars, trucks or forms.

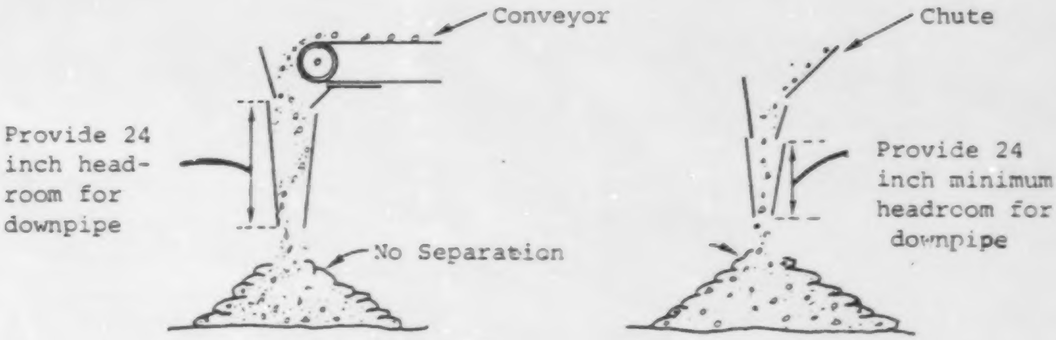

Conveyor
Chute
Provide 24 inch headroom for downpipe
Provide 24 inch minimum headroom for downpipe
No Separation

Figure 29-4-2. Discharge of Concrete From Conveyor or Chute

When concrete is transferred from one conveyor belt to another, a chute-like device as shown in Figure 29-4-3 may be used, similar in function to a down-pipe, to prevent separation.

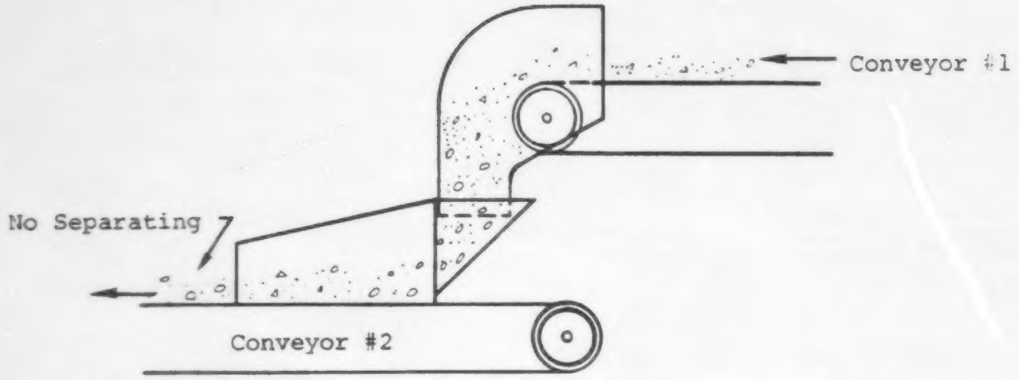
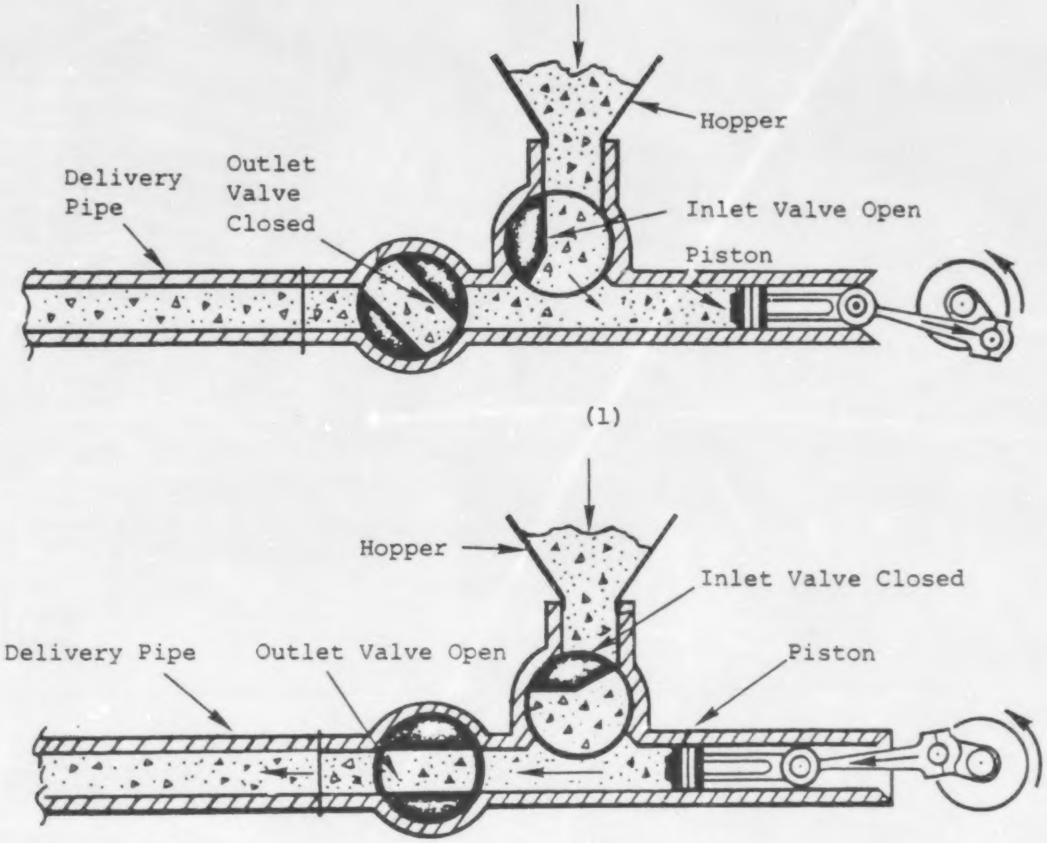


Figure 29-4-3. Transfer of Concrete, Conveyor to Conveyor

Two types of concrete pumps are shown in Figures 29-4-4 and 29-4-5, the piston type and squeeze pressure type. In the piston type, concrete is discharged into the hopper, the inlet valve opens while the outlet valve is closed, and the piston action draws concrete into the cylinder. The outlet valve then opens, the inlet valve closes, and the piston pushes the concrete from the cylinder into the delivery pipe.

In the squeeze pressure pump, the concrete is deposited in the collecting hopper, where rotating blades push it toward and into the flexible rubber pumping tube. Continuously rotating rollers rotate on the flexible tube, squeezing it between the rollers and the drum interior, and force the concrete through and out of the tube into the delivery hose.


Hopper
Delivery Pipe
Outlet Valve Closed
Inlet Valve Open
Piston
Hopper
Inlet Valve Closed
Delivery Pipe
Outlet Valve Open
Piston

(1)

(2)

Figure 29-4-4. Concrete Pump, Piston Type

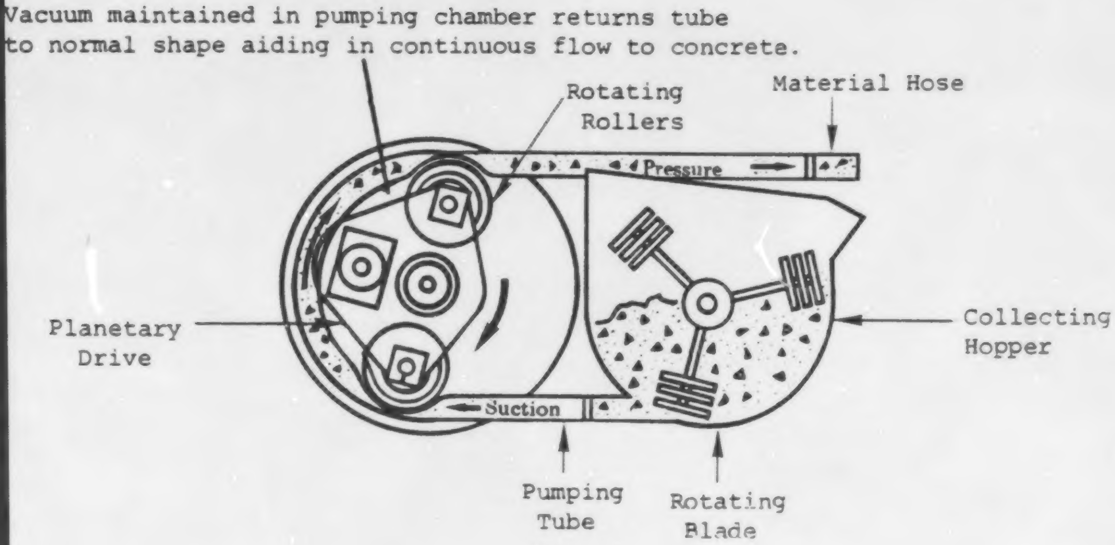

Vacuum maintained in pumping chamber returns tube
to normal shape aiding in continuous flow to concrete.
Rotating
Rollers
Material Hose
Pressure
Planetary
Drive
Collecting
Hopper
Suction
Pumping
Tube
Rotating
Blade

Figure 29-4-5. Concrete Pump, Squeeze Pressure Type

In placing concrete in narrow forms, the concrete should not be allowed to drop unrestrained and strike the form faces or reinforcing bars. Separation of aggregates will occur, resulting in honeycomb at the bottom. When discharging from a chute, buggy, bucket or wheelbarrow, a hopper feeding into a flexible drop chute should be used to contain the concrete as shown in Figure 26-4-6.

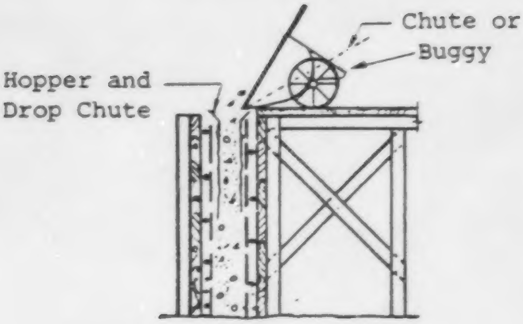


Figure 29-4-6. Placing Concrete in Narrow Forms

In placing concrete in slabs from buggies or wheelbarrows, the concrete should be dumped into the face of the concrete in place, as shown in Figure 29-5-7.

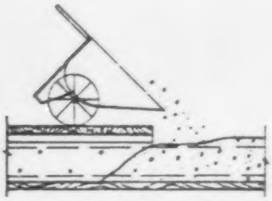


Figure 29-4-7. Slab Concrete Placement

Concrete placed on a sloping surface, discharged from a chute should be restricted with a baffle at the lower end of the chute and allowed to drop a minimum distance into the concrete in place, as shown in Figure 29-4-8. As the placed concrete moves up the slope, the chute is moved upward to allow discharge into the face of the concrete in place.

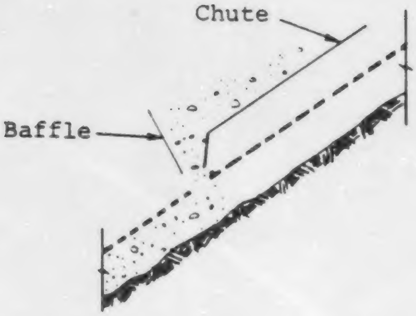
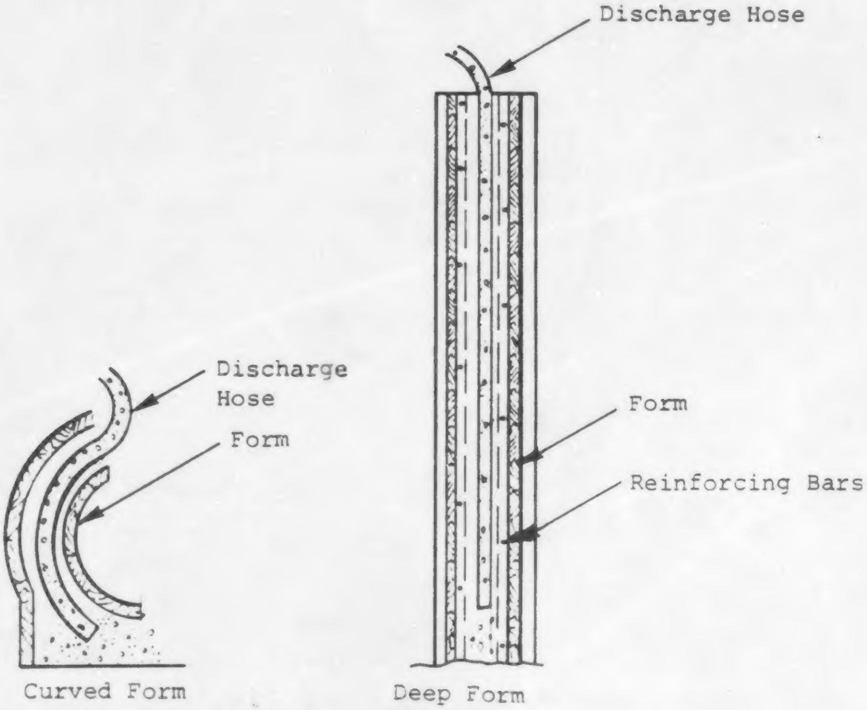

Chute
Baffle

Figure 29-4-8. Concrete Placed on Slope From Chute

When placing concrete by pumping in a deep or curved wall form, the discharge pipe or hose must extend to the bottom of the form and be moved upward as the form fills, as shown in Figure 29-4-9. Allowing the concrete to free-fall from the top of the form will result in segregation.

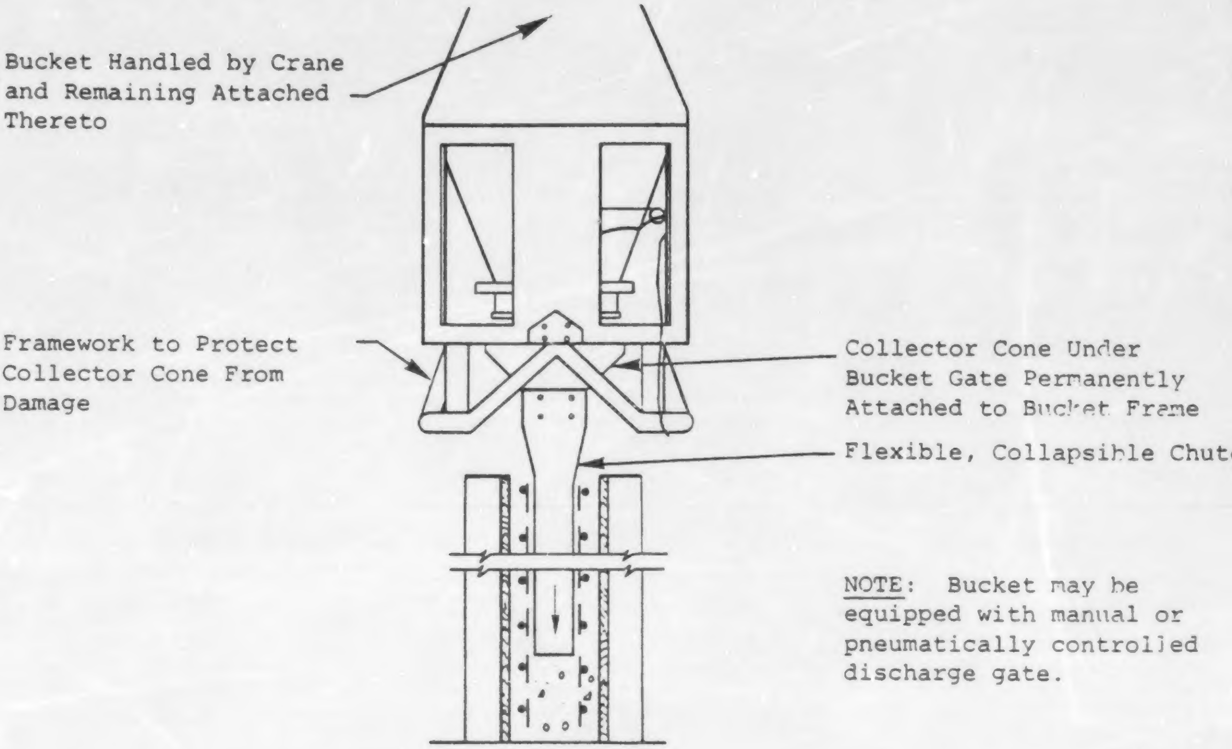

Discharge Hose
Discharge Hose
Form
Form
Reinforcing Bars

Curved Form

Deep Form

Figure 29-4-9. Placing Pumped Concrete in Curved or Deep Forms

When concrete is placed directly into forms from a crane handled bucket, a flexible drop chute is generally used, attached to the collector cone. The type illustrated in Figure 29-4-10 has a chute which collapses flat when concrete is dropping, allowing it to be used with any size aggregate.


Bucket Handled by Crane and Remaining Attached Thereto
Framework to Protect Collector Cone From Damage
Collector Cone Under Bucket Gate Permanently Attached to Bucket Frame
Flexible, Collapsible Chut

NOTE: Bucket may be equipped with manual or pneumatically controlled discharge gate.

Figure 29-4-10. Concrete Placement From Crane-Handled Bucket

Tremie placement is a method used to place concrete underwater, and consists of feeding the plastic concrete from above the water surface through a vertical pipe by gravity flow under the surface of fresh concrete previously placed. The concrete flows outward from the bottom of the pipe, pushing the surface of the concrete outward and upward. As long as the flow of concrete is smooth and the surface adjacent to the water is not agitated, the surrounding water is displaced by the denser concrete, and high quality concrete will result. Concrete placed by this method is used primarily for cofferdam seals, and for underwater structural sections such as bridge piers and tunnel construction. Curing conditions in the underwater environment are excellent, and the resulting shrinkage is very low.

Consolidation, also called compaction, is the process of removing entrapped air (air voids) from fresh concrete in the form. Freshly mixed and placed concrete is usually honey-combed with entrapped air, which if allowed to harden in that condition, will produce concrete that is weak, porous, and poorly bonded to reinforcing steel.

The amount of consolidation that is required depends on the workability of the mixture, or the ease with which it can be handled and consolidated. The workability is controlled by the consistency of the concrete, or its ability to flow.

The consistency of the concrete, or its wetness, is normally measured by the slump test. The slump test provides a check on the water-cement ratio and probable strength of the mixture. In making the test, a sample of concrete is placed in an open-ended, sheet metal mold shaped like the frustrum of a cone, resting on a flat surface. It is 12 in. high and has a top diameter of 4 in., and a bottom diameter of 8 in. The mold is filled in a certain manner with the concrete, the top surface struck off even with the top of the mold, and the mold lifted vertically and removed. The distance which the top surface of the molded concrete drops is called the slump. A stiff mixture will have a small slump, and a fluid mixture a large slump.

The values of slump for the entire range of concrete consistencies used in construction are as follows:

Concrete Consistency Description	Slump, Inches
Very Stiff	0
Stiff	0 to 1
Stiff Plastic	1 to 2
Plastic	3 to 4
Flowing	5 to 7

Consolidation of freshly placed concrete may be accomplished manually or mechanically. Plastic mixtures may be consolidated manually by rodding, e.g., thrusting a tamping rod or other suitable tool into the concrete. A form of rodding called spading is sometimes used to improve formed surfaces. Spading consists of inserting and withdrawing a flat, spade-like tool adjacent to the form.

The most widely used consolidation method is the mechanical technique of vibration. Vibration may be either of the internal or external type, and is especially adapted to the stiffer consistencies associated with high quality concrete. Vibration consists of subjecting fresh concrete to rapid vibratory impulses which liquify the mortar and reduce the internal friction between the aggregate particles. While in this condition, the concrete settles under the action of gravity, and entrapped air rises to the surface, eliminating voids. The liquified mortar mixture tends to flow laterally against the form and around the reinforcing steel.

External vibrators, such as form vibrators and surface vibrators, are seldom used in plant construction work. Internal vibrators, often called "spud" or "poker" vibrators, are used predominantly. This type of vibrator has a vibrating casing or head, is immersed in and acts directly against the concrete, with the vibratory impulses emanating at right angles to the head. Internal vibrators are commonly used having either electrical, pneumatic, or mechanical (flexible shaft) drives.

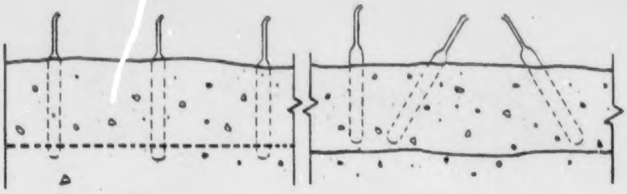
Concrete is normally deposited at close intervals, as level as possible, in layers of 12 to 18 in. The vibrator should not be used for moving the concrete laterally, since segregation might be produced. The vibrator is inserted vertically into the concrete at uniform spacing over the entire area of the placement. The area visibly affected by the vibrator should overlap the adjacent just-vibrated area by a few inches. The vibrator should be inserted rapidly to the bottom of the layer, and at least 6 in. into the preceding layer if there is such. It is then held stationary until the consolidation is considered adequate, and then withdrawn slowly. Normally, the concrete will move back into the space vacated by the vibrator.

The determination of adequate consolidation is based mainly on the surface appearance of each layer of concrete. The principal indicators of well consolidated concrete are:

1. Embedment of large aggregate
2. General leveling of the batch
3. Blending of the batch perimeter together with concrete previously placed
4. Thin film of glistening mortar on the surface
5. Cement paste showing at the junction of the concrete and the form

6. General cessation in escape of large air bubbles at the surface

Figure 29-4-11 illustrates the correct and incorrect methods of consolidation with vibrators.



Correct

Vertical Penetration of Vibrator a Few Inches into Previous Lift (Which Should Not Yet be Rigid) At Systematic Regular Intervals Found to Give Adequate Consolidation.

Incorrect

Haphazard Random Penetration of the Vibrator at All Angles and Spacings Without Sufficient Depth to Assure Monolithic Combination of the Two Layers.

Figure 29-4-11. Vibrator Consolidation Methods

Undervibration can occur when consolidation is rushed or inadequate equipment is used. Typical imperfections resulting from ineffective vibration are honeycomb, excessive entrapped air voids, sand streaks, stained "pour" line, and lack of bond to reinforcing steel.

Overvibration occurs less commonly, and is usually due to carelessness. Normal weight concretes which are well proportioned and have the recommended slump are not readily susceptible to overvibration. If it does occur, the following deficiencies may result: settlement of coarse aggregate, loss of most of the entrained air in air-entrained concrete, and sand streaks in architectural-type concrete.

GROUT PRODUCTION AND PLACEMENT

Grout is usually known as a thin, fluid mortar used for filling spaces, such as cracks in concrete foundations, and in the post-tensioned tendon tubes which are used in some containment structures. The term "grouting" usually means "pressure grouting". Pressure grouting consists of forcing the fluid mortar into such locations as those mentioned above with the use of pumping equipment. Grouting operations are generally sequenced to avoid compressing air in pockets or between adjacent grouting holes; in some locations, separate air vents are required. During pressure grouting operations, pressures and methods are generally monitored continuously to preclude disruption or undue movement of parts of the structure.

The material used for pressure grouting consists of a water-cement mixture, which is usually mixed with violent agitation, and is used within 1-2 hours after the cement is wetted. When used for filling voids larger than cracks of about 1/8" wide, fine sand is added to the mixture.

The filling of voids under machinery base plates, column base plates, and around anchor bolts in concrete is also known as grouting. The mixture used for this purpose is known as dry mortar or dry-pack, and usually consists of one part cement to three parts of well-graded fine sand (by weight), with only enough water added to dampen the mixture. When properly mixed, a mass of mortar squeezed in the hand will retain its shape. In mixing the materials, the cement and sand are thoroughly mixed dry, followed by the addition of water.

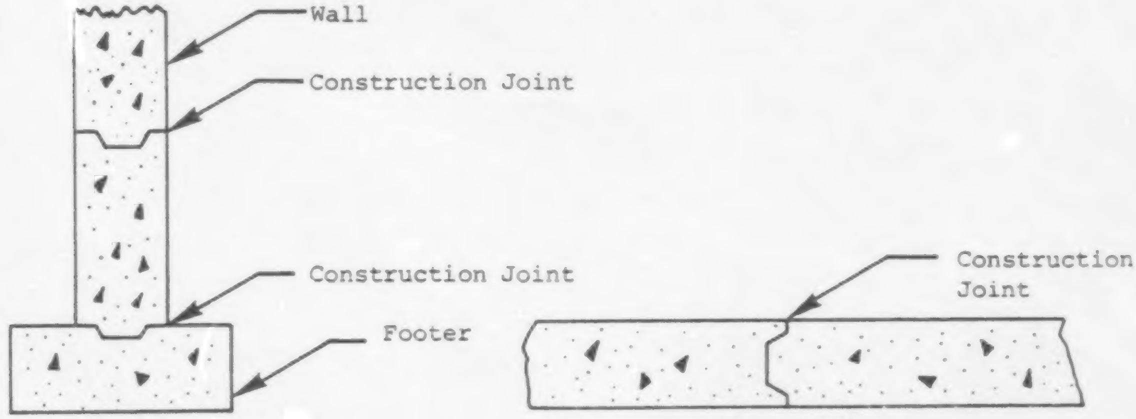
In preparing an area for dry-pack grout, the base concrete is roughened or chipped, all dust and debris removed, and the surface saturated with water for several days. Just prior to the packing operation, all excess water is removed and a thin layer of cement paste is scrubbed onto the base surfaces as a binding agent.

Packing under the base plate or other item is then done by backing up one side of the open space and ramming the grout in from the other side with paddles of suitable size, shape and length. When the space between the plate and the base has been filled, the back-up block should be removed and the face of the grout rammed from the opposite side. The exposed grout surfaces are then finished by striking off the excess and smoothing with a trowel.

Another common method for filling under base plates and around anchor bolts is the use of flowable expansive grout or nonshrink grout. With these materials, grout is flowed underneath the base plate in a confined space in a manner to completely fill the space without entrapped air pockets. Expansive grouts expand to offset shrinkage during curing, and nonshrink grouts are compounded to cure without shrinkage. Either of these types of grouts are available as field-mixed materials, or as proprietary premixed materials to which water only is added in the field.

CONSTRUCTION JOINTS

It is usually impossible to pour a large concrete structure in one single, monolithic pour, and joints referred to as construction joints should be used at any location where the concreting is interrupted long enough at any time for the placed concrete to harden. Construction joints are placed vertically in slabs at predetermined areas of low stress, or at locations where concreting operations are conducted for the day, and are placed horizontally in walls at the top of each list. Figure 29-4-12 illustrates these types of construction joints.



Wall Section and Footer

Slab Section

Figure 29-4-12. Typical Construction Joints

Specifications may require the roughening of surfaces or the insertion of dowel bars at construction joints. If only a few hours have lapsed between lifts, roughening or cleaning of the surface may not be necessary. When cleaning is necessary, wire brooming or air-water jets are adequate for use on "green" concrete (concrete usually less than 24 hours old); on older concrete, however, wet sand blasting may be required to remove surface film and contaminations.

Massive, thick concrete mats, such as those found in the foundations of nuclear power plant containment structures, are placed in several vertical lifts. Such structures are usually required to have good bond and integrity between layers, and to achieve that, the horizontal surfaces must be cleaned to remove any laitance and to expose the coarse aggregate surfaces. (Laitance is an accumulation of fine particles at the surface due to an excess of mixing water.) Such cleaning is usually done on the concrete in the "green" state with air-water jets, and is known as green-cutting. Following this cleaning process, the surface should be kept damp by flushing with water until the new concrete is placed or until the specified time of curing has been fulfilled.

CONCRETE FINISHING AND CLEANUP

The surface of finished concrete is that part which is subjected to the most severe weather conditions of wetting and drying, freezing and thawing, and wear. The physical condition of the surface, then, is as important as its appearance.

Uniformed surfaces such as those of slabs and pavings, must be worked as little as possible during early finishing operations. The fresh concrete is rough leveled, and spread evenly ahead of the strike off screen. Any water brought to the surface by the float used in rough finishing should be allowed to evaporate before the surface is again floated or troweled. If the amount of water or laitance is excessive, it should be scraped off before the surface is floated again. To secure a smooth, durable surface, final troweling should be delayed as long as possible. Usually the proper time is the time at which the surface can no longer be dented with the finger. If the surface is troweled too soon, a layer scum or laitance is formed on the surface; if troweling is done too late, the partly hardened concrete either is crumbled by the trowel or it is too hard to be troweled effectively.

During final troweling, heavy pressure should be exerted on the trowel to compact the cement paste and form a dense, hard surface. Concrete at edges at joints should generally be edged with an edging trowel and surplus mortar cleared away.

The quality of formed surfaces and finishing work required depends on factors such as the uniformity and consistency of the concrete mix, water content, air content, method of placement, and adequate consolidation or vibration. Usually the concrete has acquired a considerable degree of hardness by the time the forms are removed. The finish that is required may range from simply "knocking the fins off" and repairing imperfections, to one of several types of decorative finishes.

Areas with defects such as honeycomb should be repaired at once, as hardening continues with time. Such areas should be excavated or cut out to a depth at which good concrete is exposed, and filled with concrete matching that of the structure. Rough areas and high spots should be rubbed or ground down to the proper plane and acceptable degree of smoothness. Holes left by tie rods should be packed with stiff mortar and smoothed out to belnd with the surface. A common surface treatment is to "sack rub" the surface. A creamy slurry of cement, sand and water is rubbed onto the surface with clean burlap bags or sponge-rubber floats so as to fill all surface pits and air bubble holes. Surplus material is removed by rubbing a second application of a dry mix of the same proportions and materials onto the surface, while the first application is still plastic. This method leaves material only in the depressions and none visible on the surface. Formed surfaces finished in this manner will be sealed to the weather, and exhibit greater durability under freezing and thawing conditions.

RECORDS

Accurate record-keeping is a large and important task in the construction of a nuclear power plant and for many other large construction projects. Records are used to provide evidence that: (1) acceptable materials were used, (2) required inspections were performed, (3) correct materials were installed in the proper place, (4) materials, such as concrete, were properly mixed or prepared, and (5) materials were properly installed, in accordance with the applicable procedures. Records are also used to assist the construction managers and supervisors in controlling and scheduling work in proper sequence with optimum usage of manpower.

The records generated by construction supervisors or the job engineer may include:

- general construction progress reports
- quantities of work performed
- work/manpower scheduling
- materials received and on hand
- extra work performed
- acceptance of parts of structures completed

In the batching and placement of concrete, records are extremely important. Many of the records produced relative to concreting operations are prepared by inspectors. These records may include:

- component materials acceptance
- inspection of concrete batching, placement and curing
- materials testing

Before concrete is batched and placed, many checks have to be made to verify that the area is ready to accept the concrete. Some projects use a "Concrete Pre-Placement

Check-Out Record" form, such as the one shown in Figure 29-4-13, to document this verification. In this case, the Job Engineer would complete the information on the upper part of the form, and the appropriate Craft Supervisor and Field Engineer check and sign-off each check-out item as they are completed. When all items have been checked, the Quality Control Inspector signs the form, releasing the area for concrete placement.

A Quality Control Inspector usually performs an independent check of the area before concrete placement. A typical "Inspector's Concrete Pre-Placement Checkout Sheet" is shown in Figure 29-4-14, which lists most of the items for checking. Such forms are normally retained along with the other project Quality Control records.

Actual concrete placement is usually witnessed and inspected by a Quality Control Inspector. Figure 29-4-15 illustrates a typical "Report of Concrete Placement" form which records the identification and location of the pour area, acceptability of forms and reinforcement, equipment used, and method of delivery of concrete to the forms and consolidation.

Following the placement in the forms and initial set of the concrete, the curing process begins. Figure 29-4-16 shows a typical "Daily Concrete Curing Record" form, which is prepared by the Job Engineer and turned over the Quality Control Inspector. The Quality Inspector then performs a daily inspection, for a specified time period, and records the concrete temperature and verifies that proper cover or protection, and designated curing method is being used.

Similar records are maintained for batch plant operations, concrete delivery tickets for each load transported, component materials testing, concrete cylinder testing, grouting operations and sample tests, reinforcing steel bar test, and reinforcing steel bar splice weld tests.

Pour Area: Type Pour:

Location:

Strength Required:

Quantity Required:

Mix Code No: Cement:

Finish Required: Grout:

Date & Time Scheduled to Pour:

Date:

Superior Engineering, Inc.
Skunk Holler Nuclear Station

Curing Req'd.: Durability ☐
Load Bearing ☐

Class Struct.: Very Thin ☐
Thin ☐
Mod. Mass. ☐
Massive ☐

Checkout Item	Craft Supervisor	Field Engineer	REMARKS Minor Items to Complete Prior to Placement (if none, print "none")
1. Surface Preparation			
2. Formwork			
3. Reinforcing Steel			
4. Sleeves and Block-Outs			
5. Embedded Misc. Iron			
6. Anchor Bolts			
7. Piping Embeddments			
8. Electrical Embeddments			
9. Line and Grade			
10. Quality Con. Rel.			

Item 10 must be signed and copies given to Concrete Placement Supervisor and Job Engineer prior to issuing initial order to batch concrete.

Distribution:
- Project Superintendent
- QC Supervisor
- Concrete Placement Supervisor
- Test Lab

Job Engineer

Figure 29-4-13. Concrete Pre-Placement Checkout Record

Superior Engineering, Inc.

Skunk Holler Nuclear Station

Pour Area: ________________

Location: ________________

A. Concrete Schedules, Pour Sheets, Plans:
- __ 1. Completeness
- __ 2. Craft Cert. of Readiness
- __ 3. Updated & Available of Plans

B. Subgrade:
- __ 1. Compaction
- __ 2. Vapor Barriers Installed
- __ 3. Perimeter Insulation
- __ 4. Condition of Materials Used

C. Construction Joints:
- __ 1. Laitance Removed
- __ 2. Proper Location
- __ 3. Expansion Joint Materials
- __ 4. Contraction Joints and Filler
- __ 5. Spalling

D. Forms:
- __ 1. Form Surface
- __ 2. Panel Joints
- __ 3. Bracing
- __ 4. Tie Spacing
- __ 5. Make-Up of Ties
- __ 6. Waler Spacing & Size
- __ 7. Spreaders
- __ 8. Grout Leaks
- __ 9. Form Coating
- __ 10. Chambers Where Necessary
- __ 11. Grade Strip Properly Installed
- __ 12. Pumb Bob Lines Installed
- __ 13. Horizontal Form Liner Installed
- __ 14. Horizontal & Vertical Alignment
- __ 15. Installation of Keyways on Previous Cone
- __ 16. Proper Metal Lath Bulkhead Clearance

E. Blockouts:
- __ 1. Proper Size
- __ 2. Proper Location
- __ 3. Internal Bracing & Shoring
- __ 4. Vibrator Holes Top & Bottom
- __ 5. Grout Tight

F. Water Stops:
- __ 1. Proper Location
- __ 2. Joint Welds
- __ 3. Supported for Conc. Placement
- __ 4. Water Stop Wedged into Keyways
- __ 5. Cleanliness

G. Embedded Items:
- 1. Anchor Bolts, Inserts, Pipe Sleeves, Pipe Conduits, Flashings, etc.
  - __ a. Proper Projection
  - __ b. Proper Location
  - __ c. All Threads Wrapped
  - __ d. Secured for Conc. Placement
- 2. Misc. Steel
  - __ a. Proper Location
  - __ b. Secured or Supported
  - __ c. Check Drawings for Type & Number

H. Reinforcing Steel:
- __ 1. Proper Spacing
- __ 2. Number & Size of Bars
- __ 3. Length of Laps
- __ 4. Length of Dowels & Alignment
- __ 5. Cadwelds
- __ 6. Ties
- __ 7. Form Clearance
- __ 8. Supports

I. Final Clean-Up:
- __ 1. Check Forms for Displacement
- __ 2. Cleanliness of All Surfaces
- __ 3. Proper Scaffolding
- __ 4. Concrete Chute Arrangement
- __ 5. Proper Type & Length of Tremies

J. Miscellaneous:
- __ 1.
- __ 2.
- __ 3.
- __ 4.

K. Additional Remarks:

L. (Reactor Building Pours Only)
- __ 1. Have Tendons Been Tested and Approved?

Ready for Placement:

____________________ ____________
Inspector Date

Figure 29-4-14 Inspector's Concrete Pre-Placement Checkout Sheet

____________________ **Skunk Holler Nuclear Station**

Pour Area: ____________________ Date: ____________________
Location: ____________________
Weather Conditions: ____________________

Forms	Initial When Accepted	Reinforcement	Initial When Accepted
Properly Coated	__	Proper Clearance	__
Free From Holes	__	Proper Support	__
Seams Tight	__	Clean	__
Clean	__	Tie Rods Type __________	__
Proper Shoring	__	Spacing ______________	__

Equipment

No. and Size of Vibrators ______________________________
Placement Equipment ______________________________
Tremie Pipes and Number __________ Size __________ Location __________

Placement

Consolidation ______________________________
Grouted ______________ Time ______________
Concrete: Lift Depth ______________ Direction of Pour ______________

Remarks:

______________________________ ____________________
Quality Control Inspector Date

Figure 29-4-15 Report of Concrete Placement

Superior Engineering, Inc. **Skunk Holler Nuclear Station**

Pour Area: ____________________ Date: ____________________
Location: ____________________

Inspect Concrete Curing for Compliance with: Summer Curing Method __________
Winter Curing Method __________

Prepared By: ____________________ Date: ____________________
Job Engineer

Summer Curing Method

☐ Covered with Wet Burlap ☐ Sealed with Curing Compound

DATE								
CONCRETE TEMP. (°F)								
MINIMUM TEMP. REQUIREMENT (°F)								
INSPECTOR'S INITIALS								

Winter Curing Method

☐ Insulated Forms
☐ Plywood Forms
☐ Wet Burlap
☐ Polyethylene, Straw & Tarps
☐ Heated & Vented
☐ Other ____________________

DATE								
CONCRETE TEMP. (°F)								
TEMP. REQUIREMENT (°F)								
INSPECTOR'S INITIALS								

REMARKS:

Quality Control Inspector: ____________________

Figure 29-4-16 Daily Concrete Curing Record

Weekly and monthly summary reports are usually prepared from daily reports, summarizing work progress and average quality of the work. Inspectors sometimes are required to maintain diaries covering work progress, delays, unsatisfactory conditions, and special instructions received. For all records, the primary objective is accuracy.

EXERCISES

1. Complete the following table to identify codes and standards used for concreting operations and the responsible technical society.

Applicable to	Society	Number and Name of Code Standard
Slump Test		
Portland Cement		
Hot Weather Concreting		
Concrete Framework		
Testing Ready Mix		
Reinforcing Bars		

2. Describe the significance of normal weight, light weight, and heavy weight concretes.

3. Describe the potential deleterious effects on concreting operations of:
   a. hot weather
   b. cold weather

4. What is meant by separation and how is it avoided?

5. What is meant by consolidation and how is it avoided?

6. Complete the following table for slump tests:

Concrete Consistency	Acceptable Slump Range

7. Describe how honey combining can occur in cured concrete.

8. Complete the following table to identify the purpose of records.

Record	Purpose
Preplacement Checkout	
Inspection Preplacement Checkout	
Report of Concrete Placement	
Daily Concrete Curing Record	

MATERIALS

The following materials are required to support this module:

1. Premixed concrete
2. Concrete forms
3. Water supply with hoses
4. Mixing trough or machine
5. Steel Rods
6. Trowels

PROCEDURES

1. Tour a construction site and observe concreting operations. Take notes on the following and discuss them in class:
    a. Method of Transporting
    b. Method of Mixing
    c. Method of Placement
    d. Method of Consolidation
    e. Tests Conducted
    f. Method of Finishing
    g. Types of Records
2. Experiment with concreting operations by mixing and placing concrete in three distinctly different manners as follows.. Take notes on visual appearance of each batch and the intervals of prior to placement, after placement, after finishing, and after removal of forms. Compare notes in class.
    a. Batch #1
        1) Mix per manufacturer's instructions

2) Wet form
3) Place concrete in form by vertical pour
4) Compact concrete by ramming steel rod vertically into form
5) After hardening to finger touch, finish with trowel
6) After 48 hours remove form

b. Batch #2
   1) Mix per manufacturer's instructions except add 50% more water than recommended.
   2) Wet form
   3) Place concrete in form by vertical pour
   4) Immediately finish with trowel
   5) After 48 hours remove form

c. Batch #3
   1) Mix per manufacturer's instructions
   2) Do not wet form
   3) Place concrete by pour at one end
   4) If necessary, concrete with steel rod or other hand tool in horizontal direction to fill form. Use minimum agitation.
   5) After 48 hours, remove form

DATA TABLE

None

REFERENCE MATERIALS

ACI, *Manual of Concrete Practice*, American Concrete Institute, Detroit, MI

PI, *Materials, Design and Control of Quality Concrete*, Protex Industries Inc., Denver, Colorado

NRMCA, *Control of Quality of Ready-Mixed Concrete*, National Ready-Mixed Concrete Assoc., Silver Spring, MD

CRSI, *Placing Reinforcing Bars*, Concrete Reinforcing Steel Institute, Chicago, Illinois

Recommended Guide Specifications for Batching Equipment and Control Systems in Concrete Batch Plants, Concrete Plant Manufacturers Bureau, Silver Spring, MD

TEST

1. Name two technical societies who publish codes and standards applicable to concreting operations and list one standard published by each of the named societies.

2. Describe the concrete represented by the following terms:
   a. Normal weight:

   b. Lightweight:

   c. Heavyweight:

3. What is the purpose of the slump test?

4. List three (3) materials used as aggregates or filler materials in concrete for radiation absorption:

   ____________________, ____________________, ________________.

5. Mark the following statements true or false:
   a. The optimum temperature for placing mixed concrete is about 90°F.

      ____

   b. The temperature of mixing water has little effect on the temperature of the mixed concrete.

      ____

   c. Accelerated set and high rate of evaporation of mixing water are characteristics of cold weather concreting operations.

      ____

   d. Concrete must be protected from freezing until required strength is attained.

      ____

e. Ice may be used in the concrete mix during hot weather operations.

____

f. Accelerating admixtures are frequently used to prevent freezing.

____

6. Why is it important to control the measurement and addition of water in batching concrete?
7. Why must mixers be operated at the proper speed?
8. Describe how concreting operations can be carried out in cold weather.
9. Describe the conditions which warrant use of ice in the batching operation.
10. Are massive concrete sections more susceptible to freezing than thin sections?
11. Complete the following statements:
    a. The primary consideration in handling and placing concrete is to avoid ____________________.
    b. Concrete conveyors are designed to operate fast with minimum vibration to minimize ____________.
    c. Concrete should be discharged into the __________ ________ of handling equipment and forms.
    d. ________________ are used in transferring concrete from one conveyor belt to another.
    e. The basic operating components of a piston type concrete pump are the ____________, ___________, and ______________.
    f. Concrete is forced through the squeeze type pump by the action of the ______________.
    g. Tremie concrete is normally used for ___________ _________ applications.
    h. Honeycomb in concrete may result from ___________ _______ or ________________.

12. Mark the following statements true or false:

a. Loss of entrained air and settlement of coarse aggregate are indicators of overvibration.

____

b. Vibrators are more useful in spreading concrete than in mixing adjacent layers.

____

c. Mechanical consolidation of concrete is also known as rodding.

____

d. Stiff concrete exhibits a very low slump.

____

e. Flexible discharge hoses or drop chutes should be lowered to the bottom of deep forms to avoid segregation resulting from free-fall.

____

13. A large compressor base plate elevated 2" above base concrete is to be set in place and grouted with dry-pack.

a. What base surface preparations are recommended before setting the base plate in position?

b. What base surface treatment is recommended prior to grout installation?

c. How should grout be installed?

d. How should the exposed grout surfaces be finished?

14. Mark the following statements true or false:

a. Premature final troweling during finishing operations may produce a layer of laitance on the concrete surface.

____

b. On unformed surfaces, light pressure should be maintained during final troweling to produce a smooth surface.

____

c. Honeycomb areas appearing on formed surfaces are inconsequential, and may be covered up with back fill.

____

d. A mixture of cement and water is frequently used as a "sack-rub" finish.

____

e. Concrete durability is enhanced by effective surface finishing and sealing.

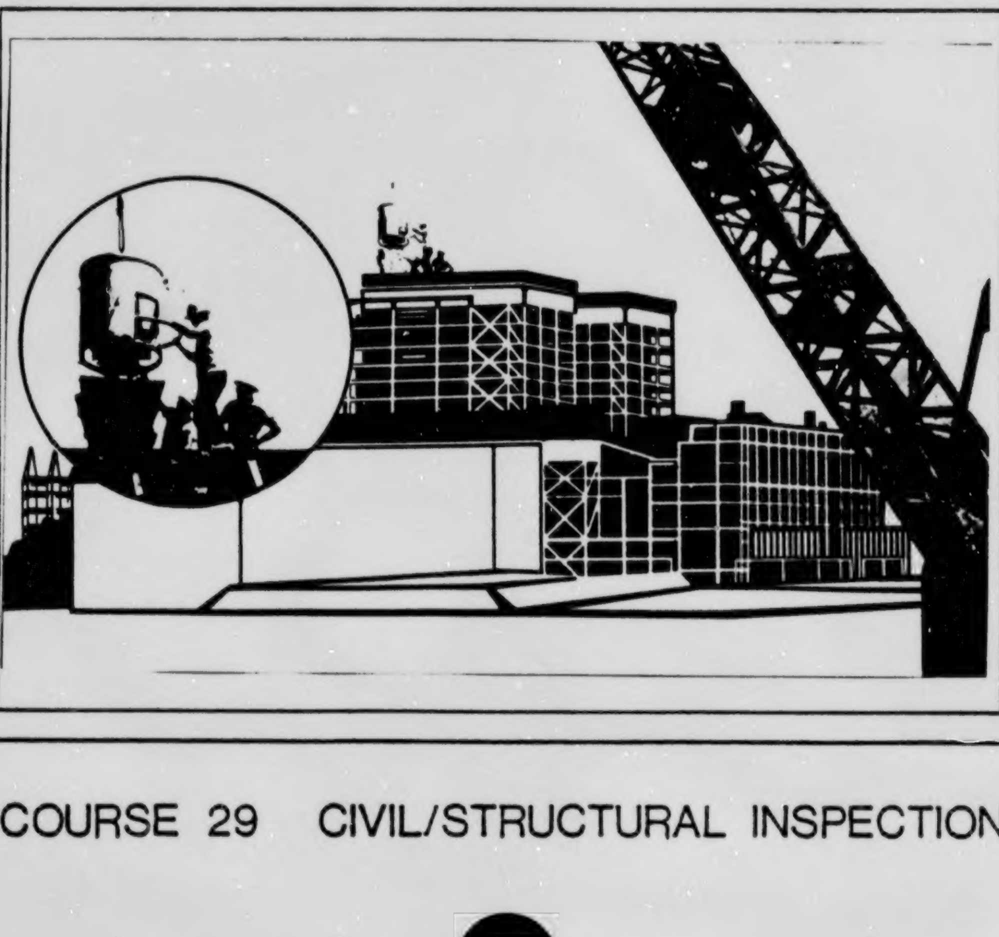
____

15. Name two record forms used for concreting operations and state the purpose of each.

NUCLEAR TECHNOLOGY

MODULE 29-5

CONCRETE TESTING AND INSPECTION



COURSE 29 CIVIL/STRUCTURAL INSPECTION

CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
4800 LAKEWOOD DRIVE WACO, TEXAS

COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

MODULE 29-1	Inspection of Construction Operations
MODULE 29-2	Structural Steel Materials, Installation and Inspection
MODULE 29-3	Concrete Materials
MODULE 29-4	Concrete Preparation, Production, Placement and Finishing
MODULE 29-5	Concrete Testing and Inspection
MODULE 29-6	Prestressed Concrete Materials, Fabrication and Inspection

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INTRODUCTION

Concrete testing and inspection generally includes the following:

- Control of batching and proportioning; tests of consistency, air content and unit weight of concrete.
- Continual inspection of the mixing, conveying, placing, consolidation, finishing and curing of concrete.
- Sampling and preparation of concrete specimens for laboratory testing.
- Observation of contractor's plant and equipment, working conditions, weather, and other items affecting the concrete.
- Witnessing of laboratory testing of concrete specimens.
- Preparation of records and reports.

Concrete is sampled and tested for two reasons: (1) to determine whether or not the characteristics of the batch conform with the specification requirements, and (2) to check for variations in characteristics within the batch as a measure of uniformity.

The inspection of concreting operations is performed to assure that the work is performed in accordance with the plans and specifications, and with good practice.

The QA/QC Technician may be trained and qualified to perform any or all of these inspection activities. This module is designed to introduce the various test methods and equipment associated with concrete testing, and to provide a practical background for the actual inspection of the associated construction activities.

MODULE PREREQUISITES

The student/trainee should complete Modules 29-1, 29-3 and 29-4 before proceeding with this module.

OBJECTIVES

Upon completion of this module, the student/trainee should be able to perform the following:

1. Demonstrate a knowledge of concrete testing techniques and equipment, including sampling, tests for concrete consistency, air content compressive strength, and analysis of test data by completing written exercises on:
    (a) sampling
    (b) applicable standards
    (c) slump testing
    (d) ball penetration tests
    (e) air content tests
    (f) cylinder molding
    (g) compressive strength testing
    (h) data analysis, including average strength, standard deviation, and coefficient of variation

2. Given the statistics on typical batcher equipment, describe the procedure for calibrating the weight scale.

3. Complete written exercises on concrete batching operations.

201

4. Complete written exercises on concrete mixing and transportation, which require the following:
   (a) listing factors which affect mixing thoroughness
   (b) calculating maximum recommended concrete capacity for a specific size truck-mixer drum
   (c) calculating the expected air content of a concrete batch after a given amount of mixing
   (d) describing the method of checking batch unformity

5. Given a typical concrete specification, devise a check list of items that should be monitored, tested and inspected during a concrete placement operation.

SUBJECT MATTER

CODES AND STANDARDS

Many codes and standards are applicable and must be followed in nuclear plant construction operations. Plant specifications and drawings are prepared to cover all plant areas and construction activities, and incorporate or invoke the applicable standards. The standards most used which cover concreting operations are published by the ASTM, American Society for Testing and Materials, and the ACI, the American Concrete Institute. Some of these standards were introduced and listed in Moduel 29-4.

Rather than describing specific standards at this point, they will be discussed at appropriate times throughout the balance of this module.

CONCRETE TESTING TECHNIQUES AND EQUIPMENT

Sampling of Fresh Concrete

In order for test results to accurately reflect the quality of the concrete, samples must be representative and tests made properly. Normally, an inspector takes samples of concrete for tests, molds the specimens in cylindrical molds, cures the specimens up to the time for shipment or test; and either ships them to a laboratory for tests, or tests them in the field as required. Sampling is performed in accordance with ASTM Standard C 172 "Methods of Sampling Fresh Concrete" as the concrete is delivered from the final mixer. This may be from a stationary mixer at a mixing plant (central mixer) or from a truck mixer (transit mixer) as it prepares to discharge concrete at the placement location.

Securing representative concrete samples requires a combination of knowledge, skill and the exercise of informed judgement. Samples which are carlessly taken will not represent the batch and cannot yield significant results from the subsequent tests.

ASTM C 172 outlines procedures for taking the samples. Samples taken for acceptance tests must consist of portions from two or more points in the batch. The portions may not be taken from the beginning or the end of a batch, and should be secured by repeatedly passing a receptacle through the entire discharge stream, or by diverting the stream completely into a container. The individual samples, or portions, are transported to the place where the fresh concrete tests are to be made or where test specimens are to be molded. They are then combined and remixed with a shovel the minimum amount necessary to ensure uniformity. Tests for slump or air content should be started within 5 minutes after sampling is completed, and finished as expeditiously as possible. Specimens for strength tests should be molded within 15 minutes after mixing the composite sample. Before testing or molding, samples should be protected from the sun, wind, and other sources of evaporation, and from contamination.

In the records which are maintained for the concrete samples, the location in the structure of the batch of concrete from which the sample is taken should be noted, together with pertinent data regarding the appearance of the mix, and temperatures of the air and the concrete.

Samples should be taken at random from any batch of concrete being placed during the run. Samples should not be taken at regular intervals, nor with any prolonged preparation that can be observed by or reported to the batching or mixing operator.

Specimens molded for strength tests should, under no circumstances, be moved or disturbed after molding, especially for the first 24 hours. Any such action may cause a deterioration in resulting strength.

Samples are also taken periodically during a pour to check concrete uniformity. The samples are secured in the same way as the increments for acceptance-test samples, but are tested separately (not combined) to reveal variations within each batch of concrete. Tests for checking uniformity may include slump, air content, unit weight, compressive strength and other properties.

Concrete Specifications

ASTM Standard C 94, "Ready-Mixed Concrete", is used by many constructors and architect-engineers as a basis for developing concrete specifications, and as a basis for purchase requirements when the concrete is purchased from subcontractors. The C 94 standard provided limits for controlling such variables as slump, air content, measurement of materials, water content, batching plant operation, mixing speeds and times, delivery methods and equipment, strength and uniformity. The concrete inspector should be thoroughly familiar with the applicable concrete specifications, and all required tests.

Slump Test

The slump test is generally considered the most useful single basis for concrete acceptance. It measured the consistency or wetness of the batch, and provides an indication of its water content. If the slump is maintained within prescribed tolerances, the mixing water content will be correct for a properly designed batch containing accurately weighed component materials. The slump, then, provides a reliable check on the water-cement ratio of the batch and the probable strength, with one exception: the slump test is not valid for concrete which has been mixed for long periods or held for long periods after mixing and to which water has been added to restore lost slump. Such practices are detrimental to concrete quality and strength even when the slump is maintained at the specified level.

The procedure and equipment is described in ASTM Standard C 143, "Slump of Portland Cement Concrete". The equipment required for the test consists only of a metal, conical shaped mold as illustrated in Figure 29-5-1, which is placed on a flat, level non-absorbent surface such as a metal plate.

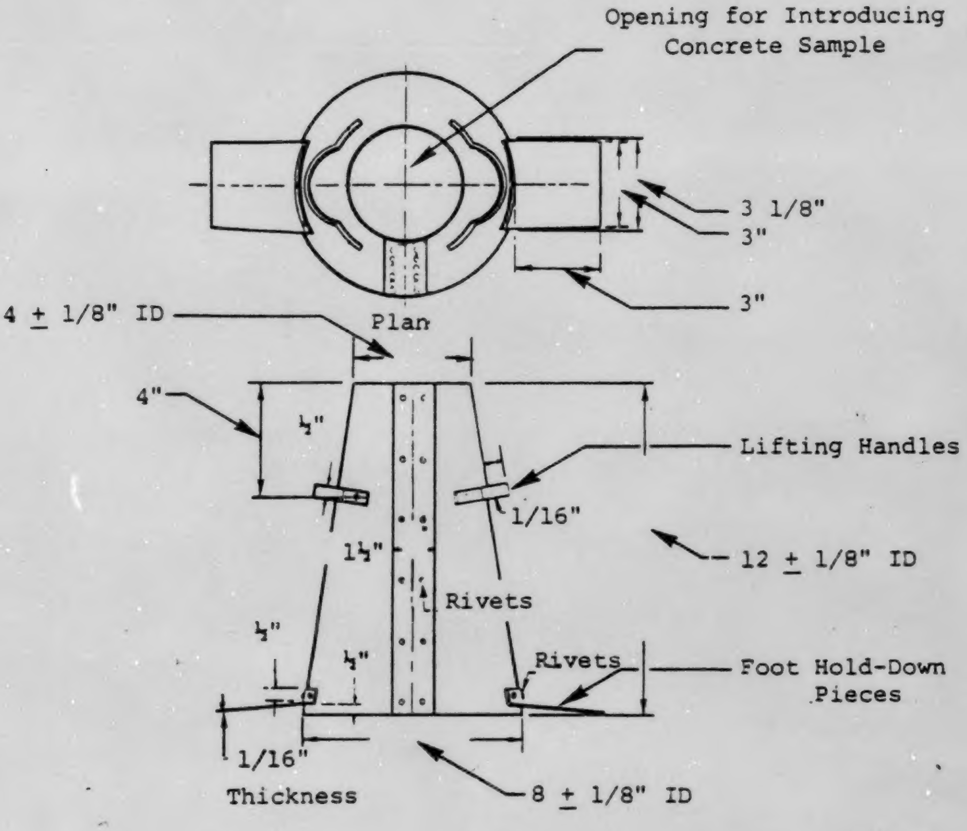

Opening for Introducing Concrete Sample
3 1/8"
3"
3"
4 ± 1/8" ID
Plan
4"
½"
Lifting Handles
1/16"
1½"
12 ± 1/8" ID
Rivets
½"
½"
Rivets
Foot Hold-Down Pieces
1/16"
Thickness
8 ± 1/8" ID

Figure 29-5-1 Slump Test Mold

Before the test, the mold is dampened with water and placed on a flat surface which also has been dampened. The test operator (concrete inspector) holds the mold in place by standing on the foot pieces, and introduces the concrete sample into the opening in the top, filling the mold in three layers of about equal volume. Each layer is "rodded" 25 times with a 5/8" diameter rounded-tip steel rod, with strokes which just penetrate the underlying layer and which are evenly distributed over the cross-section of the mold.

In placing the third and final layer, the mold should be filled to overflowing. After it has been rodded, the top of the concrete is struck off with the tamping rod so that the mold is exactly filled. The mold is then carefully removed by lifting it slowly in a vertical direction in such a manner as to permit symmetrical settlement. The entire operation of filling and removing the mold should be performed in 1 to 1-1/2 minutes. The height of the mold is then compared to the height of the settled concrete; the difference in heights, measured at the vertical axis and the top surface of each is defined as the slump. Careful removal of the slump cone is important, as any lateral motion, vibration or other disturbance usually results in a higher apparent slump value.

Tolerances and acceptance criteria for slump tests are specified in ASTM Standard C 94. C 94 provides that when the specified slump is 3 inches or less, the tolerance shall be ± 1/2 inch; when the specified slump is greater than 3 inches, the tolerance shall be ± 1 inch. If the slump falls outside of the specified limits, a second test or check test must be made. The concrete is considered unacceptable only after the failure of the second test.

Ball Penetration Test

The ball penetration test provides simple rapid check of concrete consistency. The test, as covered by ASTM Standard C 360, consists of observing the penetration of a 6" diameter, 30 pound metal ball into the surface of a sample of fresh concrete. The penetration normally measured about one-half the slump, but does not necessarily hold for all conditions of test, and is not directly proportional to the slump. It has the advantage of not requiring the molding of a specimen, and of permitting the testing of fresh concrete in wheelbarrow or other container, or even in the forms. When used by an experienced inspector, the ball penetration test can provide a reasonably accurate approximation of the slump. The test is not used quantitatively for acceptance or rejection of the concrete, but for routine checking of consistency for control purposes. Figure 29-5-2 illustrates the Ball Penetration Test Apparatus.

Air Content Tests

The amount of entrained air in concrete has a significant effect on strength and workability. Too much air detracts from strength without a compensating improvement in durability, and too little will result in poor workability and durability.

The amount of desired entrained air is specified as maximum and minimum percentages in the design mix specification. It is important that the air content is unformly close to the desired amount, batch after batch, and day after day.

Three methods for the determination of air content of fresh concrete have been standardized by the ASTM: the pressure method, and the volumetric method, and the gravimetric method. The gravimetric method is the least accurate,

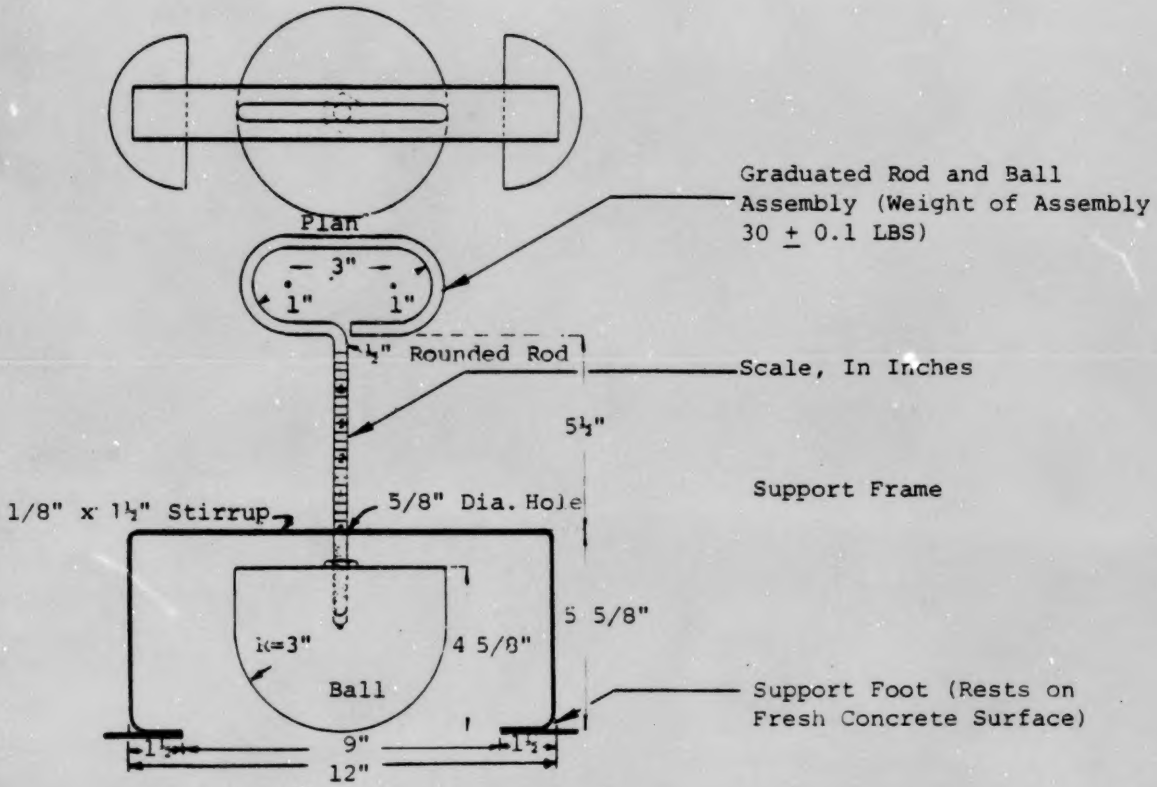

Plan
3"
1"
1"
½" Rounded Rod
5½"
1/8" x 1½" Stirrup
5/8" Dia. Hole
R=3"
4 5/8"
Ball
5 5/8"
1½
9"
1½
12"
Graduated Rod and Ball Assembly (Weight of Assembly 30 ± 0.1 LBS)
Scale, In Inches
Support Frame
Support Foot (Rests on Fresh Concrete Surface)

Figure 29-5-2 Ball Penetration Test Apparatus

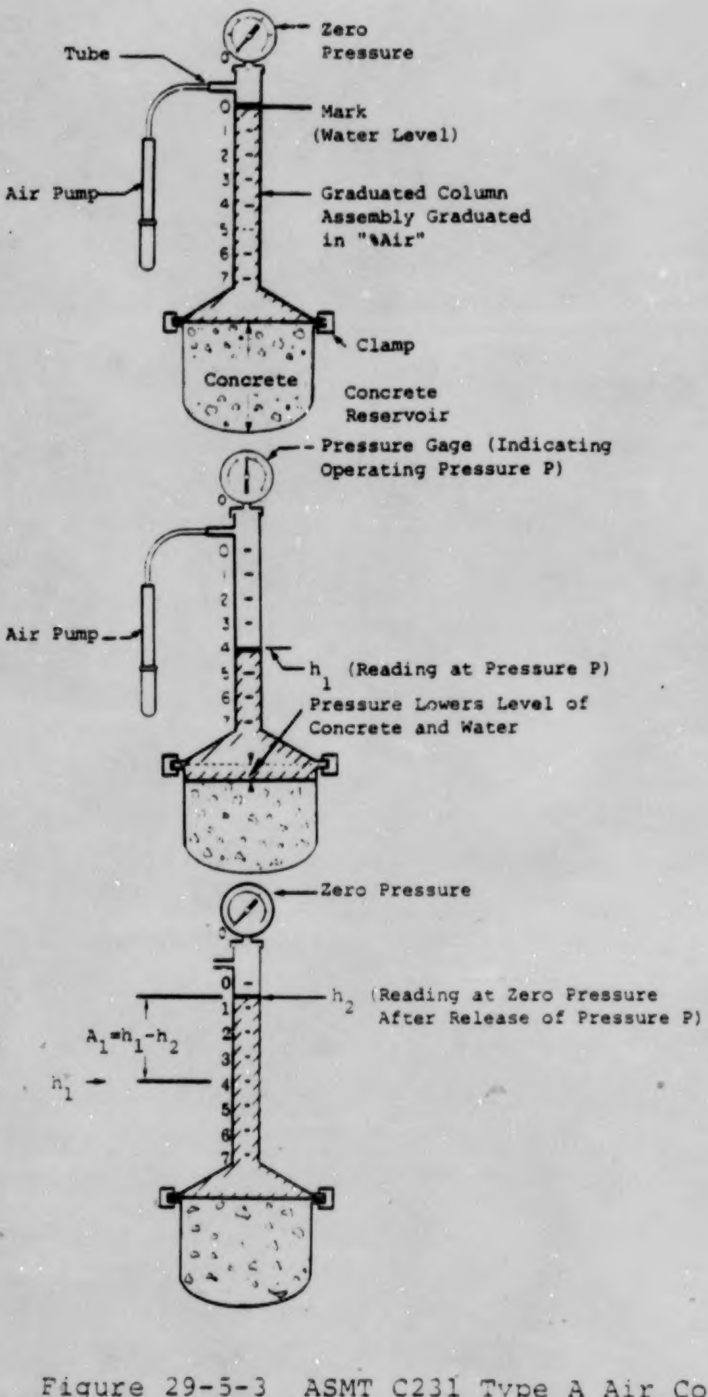
however, due to unavoidable variations in the proportions of the mix, and will not be described in this module.

The pressure method, ASTM Standard C231, depends on application of Boyle's Law: the volume of a gas (in this case, the entrained air) varies inversely with the pressure applied to it. The amount by which a known volume of concerete can be compressed when subjected to known pressure is a measure of the air contained within. Basically, the apparatus consists of a special pressure-tight container with accessories, capable of measuring precisely the volume of concrete. ASTM C231, describes two variations of this apparatus, the Type-A Meter and the Type-B Meter. The Type-A Meter is illustrated, and its operation described in Figure 29-5-3. (Please refer to the following page for Figure 29-5-3.)

The ASTM Type-B Meter provides a direct reading of percent air content on a pressure gage. With this device, as illustrated in Figure 29-5-4, water is introduced with a syringe through Petcock A to cover the concrete sample in the measuring bowl and emerges from Petcock B, while the main air valve is closed. Air is pumped into the air chamber to a predetermined pressure (which indicates as zero percent on the pressure gauge.) The main air valve is then opened, allowing the air to compress the concrete sample in the bowl. The pressure in the air chamber is reduced proportionally, and the apparent percent of air contained in the sample is read directly from the calibrated pressure gage. A correction factor "G" for air contained in the aggregate may be required, and would be determined by testing a sample of aggregate only. The air content of the sample then, $A=A_{\text{apparent}}-G$ (aggregate correction factor.)

These pressure type tests are considered adequate for all ordinary types of concrete and mortar, except those made with highly porous aggregates. They are not dependable with most lightweight aggregates.

The volumetric method consists of placing a known volume of concrete in a suitable container known as a "pycnometer", covering it with water, and then rolling, shaking or otherwise stirring the concrete to remove the air. As the water replaces the air in the concrete, the resulting reduction in volume of the concrete-water mixture is equal to the volume of air removed. This method can be used for testing most all concrete and mortar mixtures, and is particularly useful for testing concrete made with porous or lightweight aggregates for which the pressure method does not give reliable


Tube
Zero Pressure
Mark (Water Level)
Air Pump
Graduated Column Assembly Graduated in "%Air"
0
1
2
3
4
5
6
7
Clamp
Concrete
Concrete Reservoir
Pressure Gage (Indicating Operating Pressure P)
Air Pump
h_1 (Reading at Pressure P)
Pressure Lowers Level of Concrete and Water
Zero Pressure
h_2 (Reading at Zero Pressure After Release of Pressure P)
$A_1=h_1-h_2$
h_1

Operation

1. Concrete sample is placed in the reservoir and the surface struck-off even with the rim.
2. Reservoir is attached and sealed to the graduated column assembly.
3. Water is added through the tube, covering the concrete, up to the zero mark.
4. Air pump is attached to the tube.
5. Air pump is operated to increase pressure to specified operating pressure P.
6. Etrained air in concrete is compressed and level of concrete, and water in the graduated column.
7. Water level h_1, at pressure P is read and recorded.
8. Pressure P is released, and water level h_2 is read and recorded.
9. Apparent air content, $A_1=h_1$ h_2.
10. Aggregate correction factor, G_1 is determined by placing only an aggregate sample and water in the meter and repeating the test. $(G=h_{1(ag.)} - h_{2(ag.)})$
11. Air content of concrete, $A=A_1-G$.

Figure 29-5-3 ASMT C231 Type A Air Content Meter and Operation

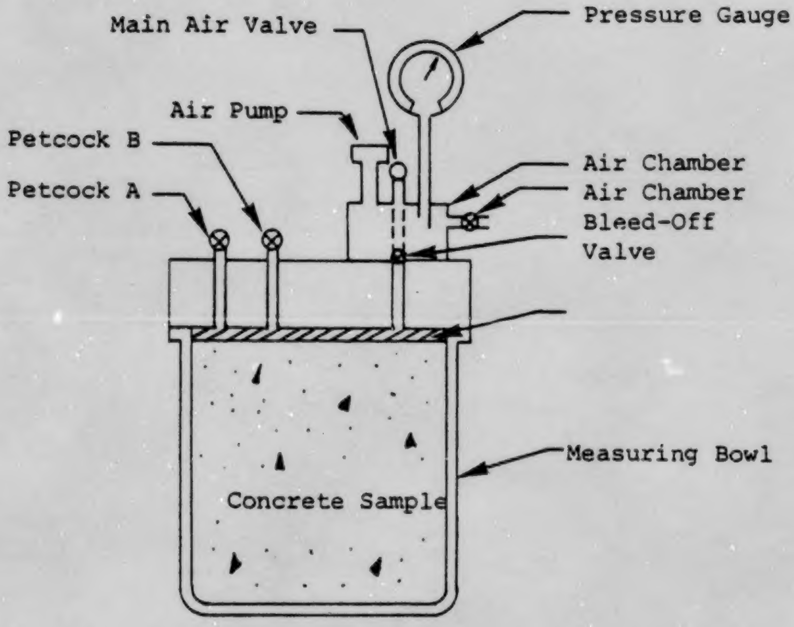

Main Air Valve
Pressure Gauge
Air Pump
Petcock B
Petcock A
Air Chamber
Air Chamber Bleed-Off Valve
Measuring Bowl
Concrete Sample

Figure 29-5-4 ASTM Type B Air Content Meter

results. Figure 29-5-5 shows the volumetric type apparatus by the ASTM.

Strength Tests

Fresh concrete samples must be molded into cylindrical test specimens and cured before compressive strength tests are performed. ASTM Standard C 31, "Making and Curing Concrete Compressive and Flexural Strength Test Specimens in the Field", is the standard used throughout the construction industry for preparing such specimens.

The molds generally used are heavily waxed waterproof cardboard tubes, measuring 6" in diameter by 12" high. They may have bottoms or be set on base plates. The molds should be placed on a smooth, firm, level surface for filling and

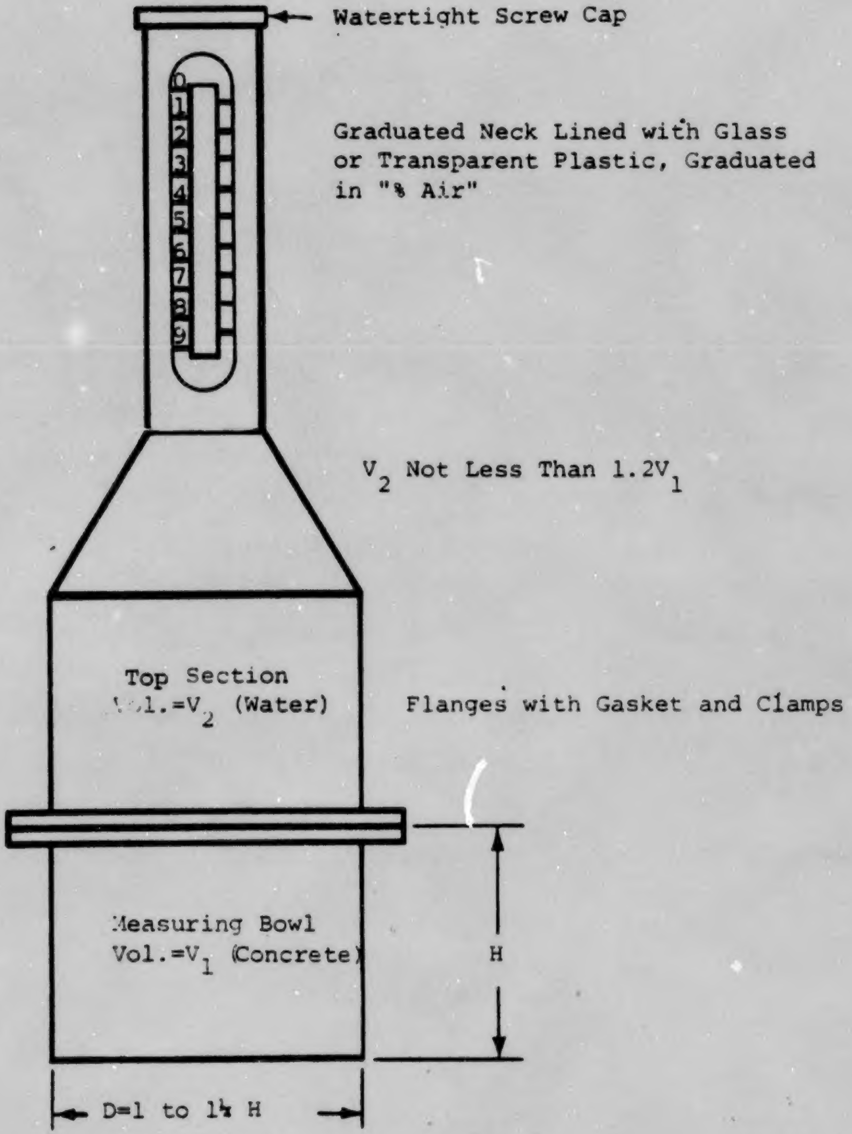

Watertight Screw Cap
0
1
2
3
4
5
6
7
8
9
Graduated Neck Lined with Glass or Transparent Plastic, Graduated in "% Air"
V_2 Not Less Than $1.2V_1$
Top Section
Vol.=V_2 (Water)
Flanges with Gasket and Clamps
Measuring Bowl
Vol.=V_1 (Concrete)
H
D=1 to 1¼ H

Figure 29-5-5 ASTM Volumetric Type Air Content Apparatus (Pyconmeter)

cast in the area where they are to be stored for the first 24 hours, protected from vibration, jarring, or other disturbance.

C 31 requires that the molds be filled in three equal layers, and each layer uniformly rodded 25 times with a 5/8" diameter bullet-nosed rod. When rodding the second and third layers, the rod should just break through into the layer beneath. The operator should attempt to add an amount of concrete in the final layer that will exactly fill the mold after compaction (rodding), or leave a slight excess. The specimen is finished by striking off the excess even with the rim of the mold and smoothing the surface with a float or trowel.

After finishing, the molds should be covered to prevent loss of moisture by evaporation, and protected from temperatures below 60^{o}F or above 80^{o}F.

Standard-cured specimens indicate the potential strength of the concrete; they are made to check the adequacy of mix proportions or as the basis for acceptance of the concrete. Field-cured specimens indicate the degree to which strength is affected by the actual conditions of temperature and moisture; they are used to determine when a structure may be put into service.

C 31, requires that standard-curved cylinders be stored in a moist condition at 73.4 ± 3^{o}F until the moment of test. The moist curing must begin when the cylinders are removed from their molds at the end of 20 ± 4 hours from the time they were cast. The specimens may not be exposed to a stream of running water, but some free water must be maintained on their surfaces at all times.

Cylinders are also removed from the molds after 24 hours for field-curing. Field-curing means that the cylinders should be stored in the structure as near to the point of sampling (or placement) as possible, and should receive the same protection from the elements on all surfaces as is given to the portions of the structure which they represent. The cylinders should be kept in the field at least three-fourths of the scheduled period of curing, then sent to the laboratory. They may be stored at laboratory temperature until 24 ± 4 hours immediately before time of testing, when they must be immersed in lime water until the time of testing to ensure uniform moisture condition from specimen to specimen.

It should be emphasized that careful standard treatment of all test specimens is absolutely necessary to obtain true, representative test results.

Concrete test cylinders must have bottom and top surfaces which are parallel and at right angles to the axis of the cylinder, as required by the C 31 standard. The surfaces should also provide uniform distribution of the compressive pressure for a valid test. To meet these requirements, the ends of the cylinders are usually capped before testing with neat cement paste, high-strength gypsum plaster, alumina cement, or sulphurous mixtures. The basic requirements for the caps is that the cap must not flow or fracture when the specimen is tested.

Sulphur caps are widely used, and harden satisfactorily for testing within 2 hours. The mixture is heated and melted in thermostatically controlled heating pots, and poured in shallow molds of the same diameter as the test cylinder. The concrete cylinder end is set in the molten material and clamped in place until the material solidifies. The capped cylinder is removed from the mold, inverted, and the other end capped in the same manner.

Strength tests are performed in accordance with ASTM Standard C 39, "Method of Test for Compressive Strength of Molded Concrete Cylinders".

The testing machines used must be of sufficient capacity, power operated, and apply the load continuously, rather than intermittently, and without shock. Most machines currently in use are hydraulic. The test pressure is applied to the end surface of the test cylinder (Diameter - 6 in., Area approximately 28.27 sq. in.) For some concrete mixtures, strengths may exceed 6,000 pounds per square inch (psi). Therefore, the test machine capacity should exceed (28.27 sq. in. x 6,000 psi = 169,620 pounds) approximately 170,000 pounds.

Compression tests should be made as soon as the test specimens are removed from the curing room as practicable. Correct, representative strength values are not obtained if the cylinders dry out partially before being tested.

The test cylinder is mounted on the test machine between spherically-seated bearing blocks. The test is started with continuous pressure loading, and continues until the cylinder fractures, recording the maximum load obtained.

In computing the unit strength of the specimen, the diameter of the cylinder is measured to the nearest 0.01 inch by averaging two diameters at right angles to each other near the center of the length of the specimen. The average area is calculated from the average diameter, and the value is divided into the maximum load recorded in the test to determine the compressive strength.

EXAMPLE:

Cylinder A - Diameter (1) - 5.93"
Diameter (2) - 5.99"
Average Diameter - 5.96"

Area $\left(\frac{5.96}{2}\right)^2$ x (3.142) = 18.60 sq. in.
Maximum test load: 79,590 lbs.

Compressive strength: $\frac{79{,}590 \text{ lbs.}}{18.60 \text{ sq. in.}}$ = 4,279 psi (or 4,280 psi)

Cylinder B - Diameter (1) - 6.01"
Diameter (2) - 6.05"
Average Diameter - 6.03"

Area $\left(\frac{6.03}{2}\right)^2$ x 3.142 = 18.95 sq. in.
Maximum test load: 80,350 lbs.

Compressive strength: $\frac{80{,}350 \text{ lbs.}}{18.95}$ = 4,240 psi

The calculated compressive strength is rounded off to the nearest 10 psi, and listed in a report for each specimen along with the following information:

- Cylinder identification number
- Diameter (average), in inches
- Cross sectional area, in inches
- Maximum load, in pounds-force
- Type of fracture
- Defects in either specimen or caps
- Moisture condition of specimen
- Age of specimen
- Slump of concrete

The number of specimens prepared and tested depends on the purpose of the tests, the use to be made of the results, and the volume of concrete placed. In most cases, two specimens are prepared and tested, and the results averaged for each single test. Complete reliance, such as for an accept/reject decision, should never be placed on a single specimen.

The magnitude of variations in strength of test specimens depends upon the control of materials, concrete manufacture, and testing. Differences in strength are generally caused by either differences in the strength-producing properties of the concrete, or apparent differences caused by discrepancies in the tests.

Analysis of Compression Test Results

Variations in the strength of concrete must be expected, but concrete of adequate quality can be produced consistently if proper control is maintained, and test results are interpreted properly. Conclusions on strength of concrete should be derived from a pattern of tests from which the characteristics and uniformity of the concrete can be accurately estimate

ACI Standard 214, "Recommended Practice for Evaluation of Compression Test Results of Field Concrete", presents the statistical methods which are generally used for evaluating strength test results.

Some of the terms used in evaluating the test data are as follows:

(1) Mean (Average), $\bar{X}$ - average strength of all cylinders.

$$\bar{X} = \frac{X_1 + X_2 + X_3 + \dots + X_n}{n}, \text{ where}$$

X_1, X_2, X_3 ... X_n are the strength results of individual tests, and n is the total number of tests.

(2) Standard Deviation, σ - A measure of variability, defined as the square root of the average squared deviations of individual strengths from their Mean.

$$\sigma = \sqrt{\frac{(X_1-\bar{X})^2 + (X_2-\bar{X})^2 + (X_2-\bar{X})^2 + (X_3-\bar{X})^2 + \dots + (X_n-\bar{X})^2}{n}}$$

(3) Range, R - The difference between the highest and lowest values in a set of data. Range is found by subtracting the lowest strength in any group of tests from the highest strength.

(4) Coefficient of Variation, V - The standard deviation expressed as a percentage of the mean (average strength).

$$V = \frac{\sigma}{\bar{X}} \times 100$$

Table 29-5-1 lists the concrete compressive strength data taken at a field batch plant over a period of a month. This data collected can be used to evaluate the degree of uniformity in producing a particular design-mix concrete. The example which follows shows how this may be done.

Table 29-5-1

Concrete Compressive Strength

Test No.	28-Day Strength, psi		X_j, Average Strength	Range, psi	$(\Delta X)^2$ or $(X_j - \bar{X})^2$
	Cylinder 1	Cylinder 2			
1	3420	3670	3545	250	4,225
2	3330	3190	3260	140	48,400
3	4030	3920	3975	110	245,025
4	2830	3120	2975	290	225,025
5	3810	3190	3500	620	400
6	3610	3210	3410	400	4,900
7	3560	3790	3675	230	38,025
8	3410	3500	3455	90	625
9	3490	3300	3395	190	7,225
10	3810	3500	3655	310	30,625
11	3510	3260	3385	250	9,025
12	3800	3200	3500	600	400
TOTAL			41,730	3,480	643,900

EXAMPLE:

Using the concrete strength data presented in Table 29-5-1, evaluate the degree of uniformity in producing a particular design mix concrete by calculating the standard deviation of the individual strengths of the cylinders, their average range in strengths and their coefficient of variation. This may be done as follows:

From Table 29-5-1, the total number of tests, n, is:

$$n=12$$

The average strength can be computed using $\Sigma X_j = 41{,}730$ psi as shown in Table 29-5-1 for all 12 tests, and therefore the average strength of all cylinders is:

$$\bar{X} = \frac{\Sigma X_j}{n}$$

$$= \frac{41{,}730}{12} - 3478 \text{ psi (rounded off to 3480 psi)}$$

Next, it is necessary to compute the standard deviation, which is a measure of the variability in the strength of each cylinder:

$$\sigma = \sqrt{\frac{(X_j - \bar{X})^2}{n}}$$

$$= \sqrt{\frac{643{,}900}{12}}$$

$$= \sqrt{53{,}658}$$

$$\sigma = 232 \text{ psi}$$

From these data, we can see that the average range, or average difference between the highest and lowest set of data is:

$$\text{Average Range} = \bar{\bar{R}} = \frac{3480}{12} = 290 \text{ psi}$$

As a result, the coefficient of variation, V, which is the standard deviation expressed as a percentage of the mean can be computed as:

$$V = \frac{\sigma}{\bar{X}} \times 100\%$$

$$= \frac{232}{3480} \times 100\%$$

$$V = 6.67\%$$

Table 29-5-2 shows the range of coefficients of variation, V, that can normally be expected on controlled projects. The ratings of control are based on experience from a large number of projects, as reported by the ACI, and are presented as a general guide in evaluation of concrete control.

Table 29-5-2

Standards of Concrete Control

Class of Operation; Overall-Variations:	V, Coefficients of Variation, for Different Control Standards			
	Excellent	Good	Fair	Poor
General Construction	Below 10.0	10.0 to 15.0	15.0 to 20.0	Above 20.0
Laboratory Control	Below 5.0	5.0 to 7.0	7.0 to 10.0	Above 10.0

Core Sampling and Testing

Specimens are frequently cut from the hardened concrete cast in the structure to verify the concrete quality. The specimens may be either beams or cylindrical cores, and are covered in ASTM Standard C 42.

Most sampling is done with the cylindrical core shape. The core specimen is cut with a length about twice its diameter, with a large hollow drill. The size drill is selected to cut a cylinder about 3 times in diameter larger than the nominal size of the coarse aggregate.

Compressive strength tests are performed on the specimens in the same manner as molded cylinders. The ends of the core are either ground smooth or capped so as to present plane surfaces against which the test load is applied. The length and average diameter of the core should be measured to 0.1 in., and the breaking strength calculated in pounds per square inch. Test reports and the analysis of test results is handled in the same manner as for molded cylinder tests.

CONCRETE BATCH PLANT INSPECTION

The consistent quality and uniformity of concrete begins with accurate batching. Accurate batching is dependent upon: (1) equipment properly maintained in good operating condition, (2) equipment properly calibrated at specified times and frequency, and (3) proper equipment operation and adherence to design mix proportions.

The inspector monitors these activities and provides assurance that these factors are properly controlled. Before batching begins, the equipment should be inspected for such items as : (1) internal cleanliness, freedom from "caked" materials or residue on hopper or chute sides, (2) clean, friction-free working parts, particularly knife edges on weighing devices, (3) loose nuts or other parts, (4) tight weighing containers and closing devices, (5) equipment correctly leveled, and (6) unobstructed view of weighing mechanism to allow observation by batcherman.

The inspector should witness scale and meter calibrations and assure that they are performed at the specified intervals. Normally, scales should be maintained accurate within a tolerance of 0.2 to 0.4 percent of the net load being weighed. Each scale should have at least 10 standard 50 lb. weights meeting the requirements of the National Bureau of Standards for calibrating and testing the weighing equipment. Using these test weights, the scales up to the full amount of the batches. The scale is first balanced at zero load, the weights are added, and the scale reading compared with the actual weight added, and the indicated reading recorded. The weights are then removed, enough material placed in the weighing hopper to produce the same scale setting obtained with the weights, and the weights, re-used to check the scale at higher loads. The scale readings for each increment of weight are recorded and the scale may then be used as a correction factor in batching.

It is recommended that the scale be balanced at zero load at least twice during each shift and checked, and should be inspected frequently for signs of sluggishness, inaccuracy, damage or sticking materials. The scale sensitivity is considered adequate when the beam or dial reacts suitably to the addition of a 5 lb. weight.

Moisture probes and automatic moisture compensation are frequently used in modern batch plants to sense the amount of free moisture in the aggregates and to make compensating adjustments in the amount of water added to the batch. These devices should be checked daily, by comparing against actual moisture tests on the aggregates, to verify proper operation and calibration.

The measurement and addition of water to the concrete batch is a critical quality factor. Most concrete specifications require that the mixing water be measured within a tolerance of one percent. Water is frequently measured by volume in a calibrated tank, but may be weighed or metered. Whichever device is used should be calibrated by measuring or weighing sample batches drawn out for various control settings. No arrangement of valves or piping should be allowed which could be used to discharge unmeasured water into a mixer that is being charged or discharged. The inspector should observe batching operations frequently and at random to assure that no indiscriminate addition of water to the mixer, for the purpose of increasing the flowability of already workable concrete, occurs.

The addition of admixtures to the concrete batch must also be rigidly controlled, as a small variation in the amount added from the required amount may produce a large variation in the characteristics of the concrete. Admixtures may be measured by weight or volume and added to either the batch or to the mixing water. The dispersing equipment should conform to ASTM C 94 and provide for visual confirmation of the correct volume of each batch and for slow enough discharge so that there is no possibility for an inadvertant double dosage.

Powdered admixtures should be measured by weight, to avoid the fluctuations which usually occur when measurement is by volume. When used in small quantities, powdered admixtures may be weighed and pre-packaged.

The following list summarizes the batch plant operations and equipment that should be inspected to verified by the inspector:

- hopper and chute cleanliness and integrity
- proper valve and closing device operation
- mechanisms intact and operating properly
- weighing equipment properly leveled
- weighing and metering equipment properly calibrated

- moisture compensating equipment calibrated and operating properly
- material proportions calculated and batched accurately, in accordance with specification

INSPECTION OF CONCRETE MIXING AND TRANSPORTATION

An essential factor in the production of uniform concrete is thorough mixing. The materials must be evenly distributed and all surfaces of the aggregates be well coated with the cement-water paste. To accomplish this effectively in minimum time, the mixer must be properly designed, in good condition, fed efficiently, not overloaded, and operated at the proper speed.

Before the batching and mixing of concrete begins for all major placements, the mixer should be examined to see that the mixing blades and interior of the drum are clean and the blades have not worn more than 10 percent from the original size. The inspector should also verify that the batch timer and counter are operating properly, and that the mixer drum is water-tight.

Stationary and truck mixers are generally equipped with metal plates stating the maximum capacity (volume of mixed concrete), mixing speed, and the gross volume of the drum. For truck-mixed concrete, the volume of mixed concrete should not exceed 63 percent of the total drum volume.

Mixing times vary with the sizes and types of mixer, and are determined by mixer-performance tests then written into the concrete specification. The batch must be mixed for the full specified amount of time to assure thorough mixing. A maximum permissible mixing time is usually established in the specification, and if the batch is to be delayed longer, the mixer should only be operated at intervals.

Most specifications limit the time the batch may be held before placement. Loss of water, slump and workability occurs with the passage of time. "Retempering", or the addition of extra mixing water, is prohibited. A loss in the strength of the hardened concrete is inevitable if extra water is added. If the concrete is not placed within the specified time or when it is still workable, it must be discarded or used for some other non-structural use.

Air content (entrained air) is also affected significantly by mixing time. Air content is usually increased by about one percent when the mixing time is increased from 1 to 5 minutes. It then remains constant for the next 5 minutes of mixing; but after 10 minutes, air is gradually lost during further mixing. All air may be lost if mixing continues for an hour.

The inspector must also monitor the uniformity of the batches being discharged. If the last portion of a batch being discharged from a mixer contains an excess of coarse aggregate (a segregated condition), the condition should be corrected by adjusting the mixer, the operating conditions, or the size of the batch. The uniformity of a batch may be checked by "washing out" samples of concrete taken from different portions of the batch as discharged; the amount of coarse aggregate in one part should not differ greatly from that in another.

Most concrete is transported from the batch plant to the placement site in truck-mixers. The inspector should check the revolution counter on each truck-mixer to confirm that the number of revolutions at mixing speed is within the specification limits (usually 70 to 100), and that others are only at agitating speed. Periodically, the counters should be checked at random at the batching point to verify that the counters are zeroed or re-set correctly before mixing and transporting begins.

The following list summarizes the items that should be checked by the inspector during concrete mixing and transportation operations:

- mixer condition, integrity and operating speed
- mixer cleanliness and blade wear
- recommended mixer loading not exceeded
- correct mixing time and speed
- enforce prohibition on "retempering"
- monitor concrete air content, slump and uniformity at discharge point
- monitor mixer revolutions at mixing and agitating speeds

CONCRETE PLACEMENT INSPECTION

The basic requirement for placing concrete is that the quality of the concrete, in terms of water-cement ratio, slump, air content, and homogeneity must be preserved. The inspector should assure that the proper methods of placing are employed that will prevent segregation and honeycombing, avoid displacement of forms and reinforcement, secure a firm bond between layers, minimize shrinkage cracking, and produce a structure of good appearance. On large projects, such methods are usually detailed in written work procedures which must be followed by all project personnel.

In general, some of the items that should be checked during placement operations are as follows:

- concrete drops should be vertical to avoid segregation.
- concrete should be dropped through pipes or chutes to avoid striking the sides of the forms or reinforcement.

- concrete should be deposited near its final location and not allowed to flow laterally for more than several feet.
- concrete should be placed directly in corners and ends of walls, and not pushed or worked into such areas.
- vibrators should be allowed to operate continuously when being inserted and withdrawn from fresh concrete.
- as a layer of concrete is being placed on a previous layer of fresh, unhardened concrete, revibration of the earlier concrete should be performed by allowing the vibrators to sink as deep into it under their own weight.
- concrete placed on a sloping surface should begin at the bottom and move upward.
- any exposed rocks and segregated aggregate should be shoveled onto softer, plastic concrete areas and thoroughly vibrated.
- spilled concrete should not be shoveled back into buckets and hoppers for subsequent use.
- when concrete is pumped, the inspector should frequently inspect the condition of the concrete being discharged for uniformity and workability.
- concrete lifts should not be placed in depths exceeding the specification requirements.
- inspectors should guard against the addition of water to the concrete batches at all times.
- rejected concrete batches (truck loads, etc.) should be identified and removed from the placement area.
- construction joints should be examined before placement for proper location and configuration.
- expansion joints should be examined before concrete placement for (a) proper joint material, (b) proper

location and alignment, (c) acceptable stability, and (d) freedom from interference with subsequent movement.

- finishing operations should be inspected for conformance to drawing or specification requirements.
- fresh concrete should be covered, if necessary, to protect from inclement weather.
- concrete must be kept moist throughout the curing period.
- forms should be removed as early as possible, and curing procedures implemented and monitored.
- curing procedures should provide for some means of retaining moisture on the concrete, such as wet burlap, cotton mats, wet sand, polyethylene film, or a sprayed sealing compound.
- finished, green concrete must be protected from subsequent damaging construction operations, such as over--loading, jarring, surface marring, or heavy impact, that is likely to disrupt the mass or damage the surface.

EXERCISES

1. Complete the following statements about concrete sampling:
   a. The ASTM Standard for sampling fresh concrete is ______________________________.
   b. The tests on concrete samples taken for slump or air content should be initiated within ___________ _______ after sampling.

c. After molding, concrete specimens (cylinders) should not be disturbed for ________________.

d. Concrete samples taken from different points in the batch and combined before testing are known as ______________________.

2. A slump test is performed on the concrete sample as illustrated in Figure A below.

   a. What is the slump of the sample?

   b. What is the tolerance of the slump value?

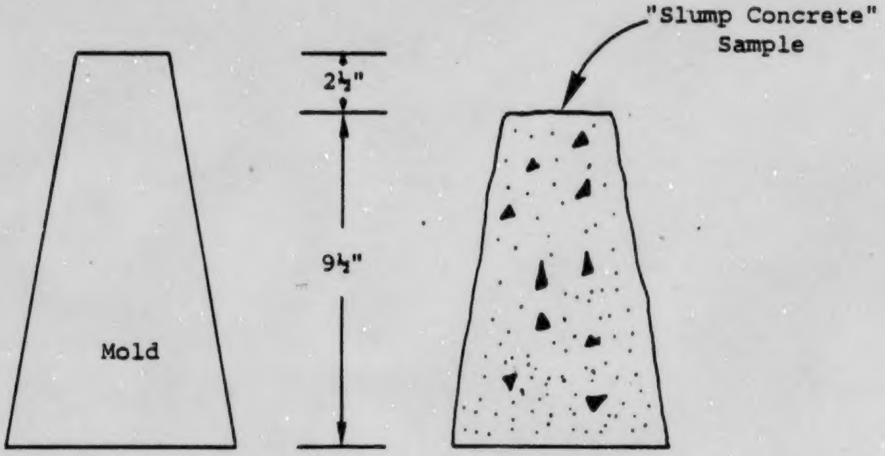


Figure A Slump Test

3. A concrete consistency test is performed as illustrated in Figure B.

   a. What is the name of this test?

   b. What is the indicated penetration depth?

   c. What is the approximate slump value, related to this depth, for normal concrete?

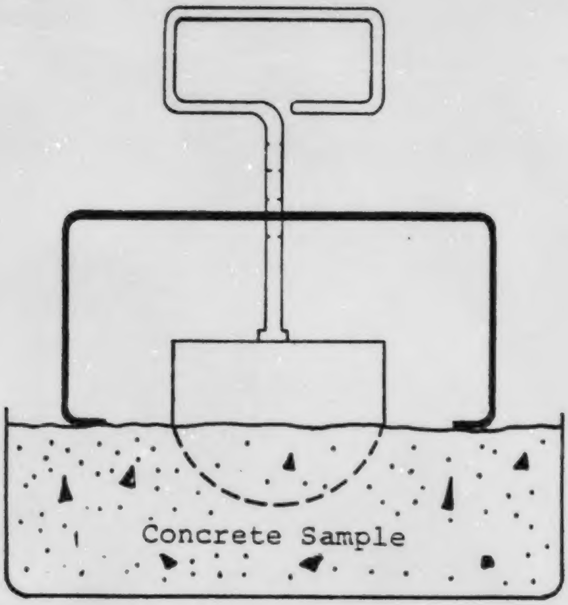
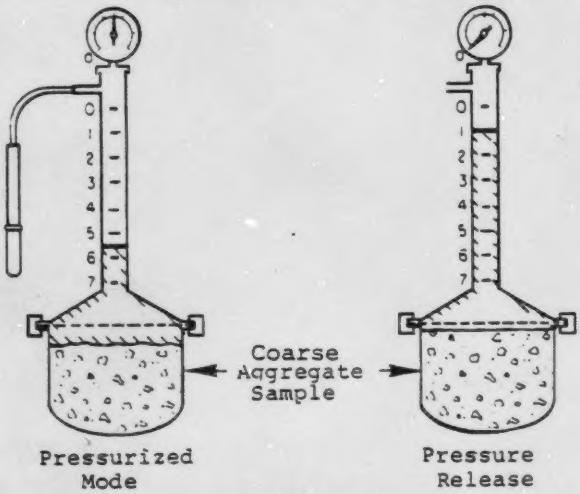

Concrete Sample

Figure C

4. A sample of concrete is tested with the air content meter shown below in Figure C.
   a. What type meter is it?
   b. What is the apparent air content of the concrete?


0
1
2
3
4
5
6
7
0
1
2
3
4
5
6
7
Coarse Aggregate Sample

Pressurized Mode

Pressure Release

Figure C

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A sample of the coarse aggregate is then placed in the meter and tested in the same manner. (See Figure D).

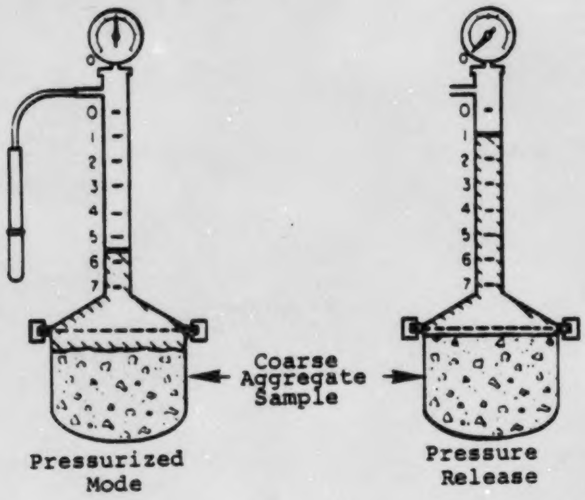

0
1
2
3
4
5
6
7
Coarse Aggregate Sample
Pressurized Mode
Pressure Release

Figure D

c. What is the air content of the coarse aggregate?

d. What is the correction factor to be applied to the apparent air content of the concrete sample?

e. What is the air content (A) of the concrete sample?

5. Molding of compressive strength concrete specimens: indicate on the sketch below, Figure E, how a concrete sample is placed and rodded in a typical cylinder mold:

(a)

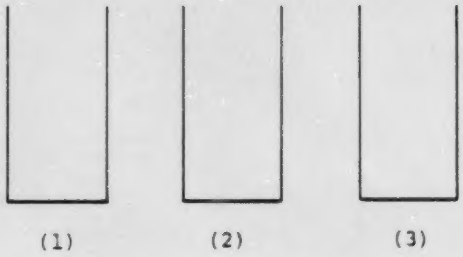


Figure E Molding of Concrete Cylinder

(b) How is the rodding performed?

(c) What is the recommended temperature range for initial curing of the finished cylinders?

6. Concrete was sampled for a large placement, and cylinders were molded for testing as shown in Table 29-5-3. The cylinders were tested, and the maximum load for each recorded in the table.

   a. Calculate the average area and the compressive strength of each cylinder, and enter in the table.

   b. Calculate the mean ($\bar{X}$), standard deviation (σ), and coefficient of variation (V).

   c. What is the rating of control of the concrete when used for general construction applications?

Table 29-5-3

Cylinder Test Data

Cylinder	Diameters, Inches	Average Dia. Inches	Area Sq. In.	Max. Test Load, lbs.	Compressive Strenth, PSI
1	5.97 5.95			65,800	
2	6.02 6.08			68,120	
3	6.01 6.09			76,760	
4	6.06 6.08			73,510	
5	5.96 5.98			64,100	
6	6.00 6.06			69,400	
7	5.99 6.05			74,280	
8	5.98 6.06			77,410	

Calculations: ($\bar{X}$, σ & V)

7. The removal of concrete core samples is covered under what standard?

8. How should a cylinder core be sized?

9. Using 10 standard 50 lb. weights, describe the procedure for calibrating a batcher scale for sand up to a capacity of 50,000 lbs.

10. Mark the following statements True of False:
    a. Powdered admixtures should be dispensed into the batch volumetrically. ____________
    b. Weighing scales should be sensitive to a 5 lb. increment of material weighed. ___________
    c. 300 lbs. of water is required for a specific concrete batch. A 5 lb. deviation from this value is usually acceptable. ____________
    d. Standard weights for calibrating concrete batching scales are usually calibrated to ASTM Standards.

       ____
    e. Automatic aggregate moisture probes and associated equipment should be checked daily for proper operation during concrete batching operations. __________

Perform the following exercises related to inspection of concrete mixing and transportation.

11. Assuming that a mixer is properly designed and in good operating condition, list the operating factors which affect mixing thoroughness.

12. A truck mixer drum is rated at a gross volume of 7.2 cubic yards. What is the recommended maximum volume of mixed concrete that may be mixed in that drum?

13. What are the consequences of "retempering" of mixed concrete?

14. After mixing a batch of concrete for 1 minute, the air content is measured at 3-1/2%. If mixing is continued for another 8 minutes due to an unexpected construction delay, what would the expected air content (in percent) be at that time?

15. How is batch uniformity, with respect to the coarse aggregate, checked at the placement site?

16. Visit a placement site in which concrete is being delivered in rotating drum mixers. Using the Procedures given in this module follow the activities of the inspector and prepare a report on the concrete placement inspection.

MATERIALS

None.

PROCEDURES

Visit a site in which concrete is being delivered for placement in rotating drum mixers as indicated in Exercise 16. Follow the activities of the inspector who is performing the concrete placement.

Using the sample check list given in Table 29-5-4 in the Data Table section of this module as a guide, prepare a report on concrete placement inspection.

DATA TABLE

Table 29-5-4

Concrete Placement Inspection Activities

Activities of Inspector	Data Complete	Remarks
1. Check mixing revolutions and time.		
2. Sample and test for air content and slump.		
3. Prepare cylinder specimens for compressive strength tests.		
4. Check for proper vertical drop of concrete into forms without striking form walls or rebar.		
5. Check for proper consoldiation (vibration) of concrete in forms.		
6. Check form integrity and security.		
7. Check for available weather protection materials.		
8. Monitor placement activities to preclude the addition of extra mixing water.		
9. Check form removal, surface repairs, and application of sealing compound within 24 hours.		
10. Assure that all appropriate records are prepared and completed.		

REFERENCE MATERIALS

ACI Manual of Concrete Practice, American Concrete Institute, Detroit, MI

Control of Quality of Ready-Mixed Concrete, National Ready-Mixed Concrete Association, Silver Spring, MD

Sampling and Testing Ready-Mixed Concrete, National Ready-Mixed Concrete Association, Silver Spring, MD

TEST

A. Answer the following questions as being either True of False.

___ 1. After molding, concrete specimens (cylinders) should not be disturbed for 72 hours.

___ 2. The tests on concrete samples taken for slump or air content should be initiated within one-half hour after sampling.

___ 3. Composite samples are concrete samples taken from different points in the batch and combined before testing.

___ 4. Powdered admixtures should be dispensed into the batch volumetrically.

___ 5. Three hundred and fifty pounds of water is required for a specific concrete batch. A five (5) lb. deviation from this value would be considered acceptable.

___ 6. Standard weights for calibrating concrete batching scales are usually not calibrated to ASTM Standards.

___ 7. Automatic aggregate moisture probes and associated equipment should be checked weekly for proper operation during concrete batching operations.

___ 8. A truck mixer drum rated at a gross volume of 7.2 cubic yards would typically have a recommended maximum volume of about 6 cubic yards of mixed concrete in that drum.

___ 9. Retempering of mixed concrete increases the water - cement ratio, and produces lower strength concrete.

___ 10. Typically, concrete batch uniformity, with respect to the coarse aggregate is checked by washing-out samples taken from the different portions of the 29-5-42 batch, and comparing the aggregates from each.

B. Answer the following essay questions:

1. Using 10 standard 50 lb. weights, describe the procedure for calibrating a batcher scale for sand up to a capacity of 50,000 lbs.
2. Assuming that a mixer is properly designed and in good operating condition, list the operating factors which affect mixing thoroughness.
3. Briefly discuss how a slump test is performed on a concrete sample.
4. A concrete consistency test called the "ball penetration test" is used for testing concrete. Briefly discuss this test and explain how it is performed.
5. Concrete is produced to the specification shown below, and delivered in rotating drum truck mixers to the placement site. The concrete is placed in a 5' deep wall form and should be cured as described below. Compile a brief list of items a concrete placement inspector should inspect, and list the sampling/specimen preparation/testing that should be performed.

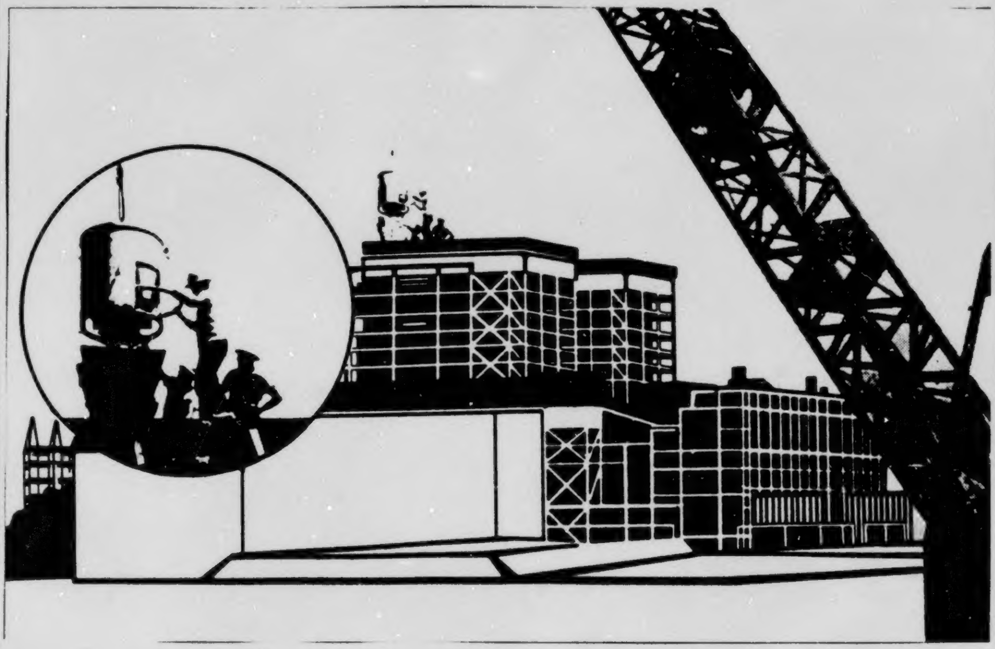
Concrete Specification

Compressive Strength: Minimum 3500 psi @ 28 days
Air Content: 3-1/2 ± 1/2%
Slump: 3 to 5 inches
Mixing: 90 Revolutions, Maximum
8 Minutes, Maximum
Finishing: Form Finish Only, Exposed Aggregate
Pockets Removed and Refilled with Grout
Curing: Sprayed Sealing Compound, within 24 hours
from Time of Placement

NUCLEAR TECHNOLOGY

MODULE 29-6

PRESTRESSED CONCRETE MATERIALS, FABRICATION, AND INSPECTION



COURSE 29 CIVIL/STRUCTURAL INSPECTION

CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

4800 LAKEWOOD DRIVE WACO, TEXAS

COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

MODULE 29-1	Inspection of Construction Operations
MODULE 29-2	Structural Steel Materials, Installation and Inspection
MODULE 29-3	Concrete Materials
MODULE 29-4	Concrete Preparation, Production, Placement and Finishing
MODULE 29-5	Concrete Testing and Inspection
MODULE 29-6	Prestressed Concrete Materials, Fabrication and Inspection

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INTRODUCTION

Inspection of activities associated with prestressed concrete is frequently performed by the trained QA/QC technician. In such a capacity, the technician is responsible for reviewing material certifications and test reports for acceptability, inspecting construction operations, performing materials testing, and preparing records and reports of inspection and testing activities.

Concrete is a universally available, relatively inexpensive, durable and easily molded construction material which is very strong in compression, and relatively weak in tension. Prestressing is a technique used to eliminate, or materially reduce, the tensile stresses normally encountered in structural concrete members. The technique involves introducing a compressive stress within the concrete member that will partially or wholly balance the tensile stresses that occur in service.

Prestressing is usually introduced in concrete by means of internal steel tendons which are stressed and then anchored. High-strength steel is currently the predominant material used for such tendons. Tendons are usually embedded in the concrete member, but can be external, as in a tie rod or a tied arch. Prestressing may also be applied by external force, such as by jacking applied at the crown of an arch or at the ends of a pavement slab.

High-quality steels and high-quality concretes are essential for producing stable pre-stressed members. The initial quality of the steel tendon is controlled by the steel manufacturer. The construction contractor is responsible for maintaining that condition by protecting it during construction operations; by proper installation, anchoring and stressing operations; and by the durability of the concrete encasement.

The concrete, which is controlled directly by the contractor, is the most critical and sensitive aspect of "prestressed concrete." The contractor controls the quality of the aggregates and water used, and the acceptance of cements and admixtures. The contractor also controls all fabrication activities: batching, mixing, transportation, form setting, tendon installation, concrete placement, consolidation and curing.

MODULE PREREQUISITES

The student/trainee should have prior training or experience in concrete materials; concrete preparation, products, placement, and finishing; and concrete testing and inspection. Completion of Nuclear Technology Modules 29-3, 29-4 and 29-5 satisfies this prerequisite.

OBJECTIVES

Upon completion of this module, the student/trainee can:

1. State the purpose of concrete prestressing.
2. Name three basic methods for prestressing concrete members and briefly describe how each method prestresses concrete members.
3. Describe the role of standards in ensuring quality of concrete materials.

4. Name three types of steel tendons used for pre- and post-tensioning.
5. State the purpose of tendon ducts.
6. Describe the techniques for pre-tensioning and post-tensioning concrete members including type of tendon, tendon installation, method of tensioning, use of reference marks, and release of tension.
7. Describe typical inspections associated with the following operations including at least two inspection attributes for each.
    a. setting of forms
    b. installation of tendons in pre-tensioned members
    c. anchoring and pre-tensioning of tendons
    d. concreting operations
    e. concrete curing and form removal
    f. de-tensioning of pre-tensioned tendons
    g. installation and post-tensioning of tendons
    h. grouting operations

SUBJECT MATTER

CODES AND STANDARDS

Standardization of methods and materials is an essential consideration for attaining the requisite quality, strength, and durability of prestressed concrete structural members. For most nuclear power plant applications, methods and standards developed by the Prestressed Concrete Institute (PCI) are incorporated in the plant specification requirements by the Architect-Engineer. Other types of construction may use standards developed by the American Association of State Highway Officials (AASHO), the American Railway Engineering Association (AREA), the American Concrete Pipe Association (ACPA), or the American Concrete Institute (ACI), as applicable.

The materials used are essentially portland cement concrete, reinforcing steel materials, and steel tensioning materials. The specifications for these materials usually require conformance to American Society of Testing and Materials (ASTM) and for American Concrete Institute (ACI) standards. The various materials used and the applicable standards are discussed later in this module in conjunction with descriptions of uses of materials.

CONCRETE PRESTRESSING METHODS

General

Concrete prestressing is a technique used to eliminate, or materially reduce, the tensile stresses normally encountered in structural concrete members. The technique involves introducing a compressive stress within the concrete member that will partially or wholly balance the tensile stresses which occur in service.

Prestressing is usually introduced in concrete by means of internal steel tendons which are stressed and then anchored. High-strength steel is currently the predominant material used for such tendons. Tendons are usually embedded in the concrete member, but can be external, as in a tie rod or a tied arch. Prestressing may also be applied by external force, such as by jacking applied at the crown of an arch or at the ends of a pavement slab. There are three basic methods for prestressing concrete structures. These are (1) post-tensioned concrete method, (2) pre-tensioned steel method, and (3) post-tensioned tendon method.

Post Tensioned Concrete Method

In the post-tensioned concrete method the concrete member is cast and hardened, and prestressed by jacking each end against abutments. No tendons or other components in tension are used. This method has had only limited use in this country, but has been used abroad in the design and construction of dams, drydocks and pavements.

Pre-Tensioned Steel Method

The pre-tensioned steel method employs steel wires or strands called tendons. The tendons are placed within the concrete form and pulled to prescribed tension between anchors prior to the placement of the concrete. While the tension is maintained, the concrete is placed and allowed to harden and bond firmly to the tendons. After the concrete attains its rated strength by curing the tendons are cut loose at the ends of the member. The tension in the tendons is transferred to the bonded concrete which compresses the concrete. Prestress is transferred only by elastic shortening of the concrete. Until the concrete has actually shortened, it is not prestressed.

The tendons used in pre-tensioned construction must be relatively small in diameter, since the bond stress between the concrete is relied upon to transfer the stress from the tendon to the concrete. A large number of small tendons are normally required to develop the required prestressing force.

Not all pre-tensioned tendon designs pass the tendon straight through the member. Instead, the member may be designed to have the tendon deflected or draped into a trajectory that approximates a curve. This technique is frequently used on large structural members, such as bridge guides and light roof slabs with integral beams.

The pre-tensioned steel method is most frequently used in permanent precasting plants, and has become a major method in this country.

Post-Tensioned Tendon Method

In the post-tensioned tendon method, the tendons are inserted through formed tubes or ducts in the concrete member after the concrete has been cast and hardened. Anchorages are then attached, and the tendons are tensioned against the concrete.

Accurate alignment of the anchorages, also called bearing plates, normal to the concrete is essential. These bearing plates must be accurately positioned and have complete bearing on the concrete beneath. In the fabrication process, the anchor plates are set in position in the ends of the concrete forms, and secured to prevent dislocation during the concreting operation.

The tendon passages through the concrete are formed either by inserting metal tubes or flexible metal hoses in the forms and concreting them into the structure, or by using inflatable rubber hoses or tubes which are removed after the concrete has hardened. Such passages formed directly in the concrete are usually flushed thoroughly with fresh water before tendon installation to remove residual material which may be corrosive to the tendon steel.

After tendon installation and tensioning, the duct is pumped full of a grout mixture, filling all of the voids. The grout hardens and cures and serves two purposes. First, grout bonds the tendon to the concrete section. Secondly, grout provides a protective coating on the tendon steel to prevent corrosion.

This post tensioning method is used for both pre-cast and cast-in-place construction. It has wide-spread use in this country, and has been used for prestressing many concrete reactor building containment structures in nuclear power plants.

Pre-Tensioning vs. Post-Tensioning

Pre-tensioning is usually associated with operations at precasting plants, and post-tensioning is usually regarded as a method of prestressing concrete at the job site. However, post-tensioned beams and roof sections are often made in precasting plants and transported to the job site for later tensioning. Also, on large projects where many pre-tensioned members are to be utilized, the contractor may set up temporary pre-tensioning facilities for on-site production of pre-tensioned elements. Each method of making prestressed concrete has particular theoretical, practical, and economic advantages and disadvantages which are considered by the architect-engineer when the basic structural designs are developed. The role of the QA/QC technician is one of verifying that the specified method is in fact used and used correctly.

PRESTRESSED CONCRETE MATERIALS

General

High-quality steels and high-quality concretes are essential for producing stable pre-stressed members. The initial quality of the steel tendon is controlled by the steel manufacturer. The construction contractor is responsible for maintaining that condition by protecting it during construction operations; by proper installation, anchoring and stressing operations; and by the durability of the concrete encasement.

The concrete, which is controlled directly by the contractor, is the most critical and sensitive aspect of "prestressed concrete." The contractor controls the quality of the aggregates and water used, and the acceptance of cements and admixtures. The contractor also controls all fabrication activities: batching, mixing, transportation, form setting, tendon installation, concrete placement, consolidation and curing.

Concrete Materials

The materials used for prestressed concrete members are essentially the same as those normally used for structural concrete: aggregates, portland cement, admixtures and water. Prestressed concrete usually weighs from 140 to 160 pounds per cubic foot, and is batched for compressive strengths from 3500 to 7000 psi.

Aggregates are usually specified to be gravel or crushed rock. For normal high strength concrete for prestressed applications, gravel produces better workability and compactability at relatively low water/cement ratios. Crushed rock of proper angularity, however, is superior for extremely high-strength concrete, but requires intensive vibration to achieve proper compaction.

The maximum size of the coarse aggregate is normally limited, with the optimum size for most applications being about 3/4 inch. Fine aggregates may range from fines into the coarse sizes. The cement-rich mixtures employed in prestressed concrete provide ample cement-paste for complete particle coating and the filling of voids. Aggregates must be free from clay coatings or particles, which effectively increase shrinkage and decrease concrete strength, Also, aggregates must be free from salt. Salt contamination, even in small amounts, reduces the corrosion-inhibiting value of the cement, and causes electro-chemical corrosion of steel reinforcing elements.

Aggregates are usually selected and used in accordance with one or both of the following standards:

- American Society of Testing and Materials (ASTM) Standard C33, "Concrete Aggregates"
- American Concrete Institute (ACI) Title No. 58-24, "Selection and Use of Aggregates for Concrete"

Cements used in prestressed concrete are almost exclusively portland cement types. The types are:

- Type I - Standard
- Type II - Moderate low-alkali and salt resisting
- Type III - High early strength
- Type IV - Low heat of hydration
- Type V - Sulfate resisting

Types I and II cements are most frequently used, and are selected for an optimum combination of early strength, shrinkage, durability and economy. Type I is suitable for most building work, but Type II provides greater durability and corrosion protection for embedded steel in coastal and marine environments having salt-air and salt-fogs.

Type III is frequently used for precast members where rapid early strength is required and shrinkage can occur without restraint. Type III is usually not feasible for cast-in-place members, due to the excessive rate of shrinkage and resultant cracking that can occur in such a restrained configuration.

It is standard practice to require that all cements used for prestressed concrete work conform to ASTM standard C150. "Specification For Portlant Cement".

Admixtures, or additives to the concrete mixture, are frequently used to obtain one or more of the following results:

- retain or improve workability while lowering the water/cement ratio
- retard initial set
- accelerate final set
- increase early strength
- reduce shrinkage

The admixtures generally used in prestressed concrete are types A or D, as defined in ASTM standard C494, "Standard Specification for Chemical Admixtures for Concrete." These materials consist of either lignosulfonates, organic acids, or polymers.

Many admixtures used in conventional concrete contain chlorides such as $CaCl_2$. Such admixtures must be prohibited from use in prestressed concrete; the chloride ion will attack prestressing tendons and result in stress corrosion and pitting. Admixtures, therefore, must be carefully selected, and employed judiciously.

The quality of the mixing water used in prestressed concrete must also be controlled for assuring proper set and maximum durability. In addition to being potable, the amounts of included salt, silt and organic materials should be restricted. Typical limitations for these impurities are as follows:

- no impurities allowed that will cause a change in time of set greater than 25% nor a reduction in strength at 14 days age greater than 5% as compared with distilled water.
- chloride ion less than 650 parts per million
- sulfate ion less than 1300 parts per million
- water free from oil

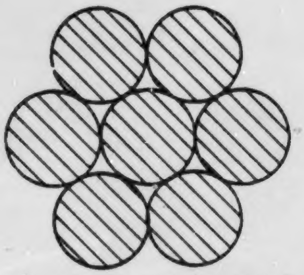
Steel Materials

Steel tendons are the most widely used materials for inducing a compressive stress into a prestressed member. Tendons are usually located inside the concrete cross section, either directly embedded, or grouted in a formed duct or tube.

Tendons must have high tensile strength and the ability to withstand indefinitely a high state of stress, with little loss due to relaxation, corrosion, or fatigue. The most commonly used materials for tendons are cold-drawn stress-relieved steel wires, stress-relieved stranded wire, and high-tensile alloy steel bars.

Cold drawn wires are frequently used in post-tensioned construction, but rarely used in pre-tensioned members due to the relatively low bond strength between the concrete and the smooth wires. Cold drawn wires are manufactured in diameters of 0.192, 0.196, 0.250 and 0.276 inches to conform to the ASTM Standard A421, "Specification for Uncoated Stress-Relieved Wire for Prestressed Concrete."

Standard wire tendons of substantial strength are produced by weaving several wires into a strand. Seven-wire strand is widely used in pretensioning and, to a lesser extent, in post-tensioning. Seven wire strands are made by twisting six wires around a slightly larger, straight central wire. After being twisted together, the strands are stress relieved, by heat treatment. Stranded tendons of this type are illustrated in Figure 29-6-1, and are fabricated to the requirements of ASTM Standard A416, "Specification for Uncoated Seven-Wire Stress-Relieved Strand for Prestressed Concrete."



Enlarged Cross-section
of Typical Seven-wire
Strand

Figure 29-6-1.

Alloy-steel bars are used extensively for post-tensioning tendons. These bars are made in standard nominal diameters from 1/2 to 1 3/8 inch from an alloy steel conforming to ASTM Standard A322, "Standard Specification for Hot-Rolled Alloy Steel Bars." The bars are cold stretched to raise the yield point and to render the bars more elastic at stress levels below the yield points. After stretching, they are stress-relieved by heat treatment to improve the ductility and stress-strain characteristics.

It is noted that reinforcing steel, usually in the form of closely-spaced small bars, is also used in most prestressed concrete members. Such steel provides unstressed reinforcement against secondary stresses and shear stresses.

Grout Materials

The grouting of post-tensioned tendon tubes or ducts may be accomplished with a flowable neat-cement-and-water mixture, or a cement-sand-and-water mixture. (A neat-cement-and-water mixture is one that contains only cement and water, and no additives or admixtures.) As in the case of the cements used in the concrete mixtures for prestressed members, portland cements which conform to ASTM Standard C150, usually type I, II or III, are used for grout mixtures.

PRESTRESSED CONCRETE FABRICATION

Concrete Mix

Most prestressed concrete used in nuclear power plants in cast-in-place and post tensioned. In some cases, however, pre-cast members are used, either of the pre-tensioned or the post-tensioned type.

The production of high quality concrete is a basic requirements for all prestressed concrete applications. The accuracy of batching is essential, as well as thorough mixing. Water content of the mixtures is kept as low as possible to minimize shrinkage and obtain high strength. It has been found that plastic concrete with a slump between 2 and 4 inches contains enough water in the mixture to permit the concrete to be properly placed and compacted, and to avoid honeycomb.

Normally, concrete mixes are trial batched, mixed and laboratory tested before use on the job. Mixes employed should have laboratory strengths 10 to 20% higher than that required by the job specifications.

Particular attention must be paid to the mixing of the concrete. Batches must be mixed in an effective mixer (such as rotating, driven-type truck mixer) at a proper turning rate and for a sufficient time to produce a uniform, homogeneous mixture. If the mixed concrete must be transported to the point of discharge and placement, it must be done with proper equipment in accordance with an established procedure (type of mixing, turning rate of mixer, method and amount of water addition, etc.) to prevent segregation of component materials and to avoid premature set or stiffening. Recommended guidelines are those established in ACI Standard 304 "Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete."

Forms

The types of forms required for the prestressed concrete structure or member depends on the type of structure or configuration of the member. For precast members, forms are designed to be re-used many times to fabricate duplicate parts. For cast-in-place members or structures, standard or modular types of forms are used where possible to minimize form construction and erection time.

For pre-tensioned members, forms are erected and reinforcing steel and steel tendons are placed into the forms. The tendons are then tensioned, then, the concrete is placed in the forms. Internal vibration is usually used to thoroughly consolidate the concrete, eliminate voids, air bubbles, and honeycomb, and to cause the concrete to flow around the reinforcing steel and tendons. Curing of the concrete begins after placement and should provide sufficient moisture to allow the completion of the chemical reactions (cement hydration) which produce strong, durable concrete. Moisture must be contained on the surface of the concrete during the curing process by means of water soaking or fogging, water-soaked mats, sealing compounds, or polyethylene sheets. The cast member normally remains in the form until the concrete attains the required strength. When the strength and the attendant bond between the concrete and the embedded tendons has been attained, the tendons are cut loose from the tensioning anchors at the ends of the member, and the member is removed from the form system.

Post-tensioned prestressed concrete may be either be precast or cast-in-place as in the case of a reactor building containment structure. In either case, the tendon tubes, ducts, or duct forming devices are positioned within the forms, along with the non-stressed reinforcing steel and other embedments. The concrete is then placed, vibrated (compacted) and cured in the normal manner. The forms are usually removed from these types of structures or members within a day. In the case of a large structure, the tendon ducts may be flushed-out with clean water and blown dry with oil-free air after several days curing time, followed by pulling the tendons into place. For cast-in-place prestressed concrete, tensioning is performed after the concrete has attained the required strength. Pre-cast, post-tensioned members are handled in the same manner, but tensioning is usually performed after the members are erected in their final position and location.

After post-tensioning operations have been completed, a grout mixture is pumped into the tendon ducts, filling all voids and surrounding the tendon steel. The water/cement ratio of the grout must be closely controlled, and the grout must be thoroughly mixed by machine to obtain satisfactory results.

TENSIONING METHODS AND EQUIPMENT

In manufacturing pre-tensioned, pre-cast members, the prestress strand or wires are anchored firmly at one end, and attached by means of strand vises or grips to hydraulic jacking equipment at the other end. The tendons are then stretched to assure equal length and starting tension. Some jacking equipment is designed to stress tendons one-at-a-time, and others to stress tendons as a group (after initial equal tensioning to a nominal value, e.g. 1,000 lbs.). Measurement of the stress imposed on the tendons is usually determined independently by direct force measurement and by elongation measurement of the tendons. Typical specifications require that the difference between the values obtained from the two methods of measurement be less than 5%.

Hydraulic pressure gages, load cells, dynamometers and other devices are used for measuring stressing loads. These devices are regularly calibrated with the calibration performed with the devices installed on the jacking system and with the system in operating condition and mode. The measurement of tendon elongation typically is done within an accuracy of 1% of the theoretical elongation.

After the concrete reaches the specified release strength for detensioning, or transfer of stress to the concrete, multiple strand arrangements are released simultaneously from both ends by flame cutting for gradual stress release and minimal movement of the member. In all detensioning operations, symmetrical release about a member's neutral axis is essential to minimize member shock or movement.

Tendons in post-tensioning systems are handled and anchored differently then pre-tensioned tendons. Wire type post-tensioning systems generally utilize 0.25 in. diameter wires with a guaranteed ultimate tensile strength of 250,000 psi.

Anchorage of most wire tendons is achieved through the use of 0.375 in. diameter button-heads formed on the individual wires by a cold up-setting process.

Stranded type tendons utilize either 0.5 or 0.6 in. diameter 270,000 psi tendons and obtain anchorage through the use of either two-piece or three-piece wedges.

Bar type tendons are comprised of smooth or specially threaded bars with diameters ranging from 1/2 to 1-3/8 in. and with ultimate strengths from 145,000 to 160,000 psi. Bars may be anchored with any of a variety of available anchorage devices, including wedges, compression grips, and threaded ends.

When stressing any of these types of tendons, an initial load of about 10 percent of the full load is applied for absorption of residual slack. During final tensioning, jacking operations are applied simultaneously from both ends of the tendon so that both the jacking force and the measured elongation will compare within 5% of computed values. When the required tension is achieved, the anchors are set, the jacking equipment disconnected, and grouting operations started.

SAFETY MEASURES FOR TENSIONING OPERATIONS

Prestressing inherently involves the use of very high forces, with steel and concrete stressed to a high percentage of their ultimate load. Tendons may be under tension to values as high as 180,000 psi, which represents a tremendous stored energy, and which can convert an anchorage into a deadly missle.

Safety of personnel and equipment can be achieved only by positive efforts, including planning, indoctrination of workmen through a safety program, and enforced safety requirements at the work site. Rules must be established including such items as the following:

- Before tensioning, all personnel not required to perform the tensioning should be warned with an audible and visual signal to leave the immediate area.
- Jacks should be secured to prevent lateral or longitudinal motion in the case of tendon failure.
- All personnel should be restricted from the areas at the end of the member or tensioning bed directly in line with the tendon being tensioned.
- Elongation measurements or tendons being tensioned should be taken by personnel from the side by jigs or templates or from behind shields, and not from above the tendons.
- Eye protection should be work by personnel performing wedging and anchoring operations to preclude injury from flying pieces of steel.

INSPECTION AND TESTING

Scope

Inspection and testing operations are usually required for all elements entering into the complete prestressed concrete system when used on nuclear power plant projects. Complete and accurate records must be maintained for the engineer, owner, inspection agency, and governmental regulatory bodies.

Materials are generally purchased to conform to applicable ASTM standard requirements. This applies to both the concrete materials, reinforcing steel, tendons, and tendon anchorage materials. When required by the purchase order, manufacturers furnish material test reports and certifications, which should be examined for completeness and acceptability by the cognizant inspector. These manufacturers' test reports should be identified with bins, cars, heats, reels or other specific lots. A records control system is usually required and used that identifies the specific materials that were used in fabricating each prestressed member.

The major activities in fabricating prestressed concrete members or structures which are subjected to inspection and test are shown in Table 29-6-1.

Table 29-6-1

Activities Subject to Inspection and Test

Pre-tensioned	Post-tensioned
Setting of forms	Setting of forms
Installation of reinforcing steel	Installation of reinforcing steel
Installation of inserts	Installation of tendon ducts
Installation of tendons	Concreting operations
Anchoring and pre-tensioning of tendons	Concrete curing and form removal
Concreting operations	Installation and Post-tensioning of tendons in ducts
Concrete curing and form removal	Grouting operations
Detensioning/stress transfer	

Inspection of Setting of Forms

Attributes typically inspected with respect to setting of forms are as follows:

- Forms adequately braced, stiffened, anchored and aligned to produce members or structures within the limits of dimensional tolerances.
- Bulkheads, spacers and templates conformance dimensionally with drawing requirements.

- Form joints smooth and tightly fit to prevent leakage of cement paste.
- All slots and holes in the forms plugged neatly so that the finished surface has a workmanlike appearance.
- Forms and beds thoroughly cleaned after each use.
- Forms and beds properly coated with form-release compound.

Inspection of Reinforcing Steel Bars and Mesh

Attributes typically inspected with respect to installation of reinforcing steel bars and mesh are as follows:

- Bars and mesh fabricated in the configuration shown on drawings and installed within specified tolerances.
- Bars and mesh supported and secured by chairs, blocking, and ties to the beds or forms to maintain its position during concrete placement and vibration.
- The ends of tie wires used to hold bars or mesh bent into the structure to provide maximum concrete cover.
- Welding on reinforcing bars or mesh permitted only as described by job specifications. (Normally not permitted.)
- Bars, which extend out of the member or structure to provide structural connection for cast-in-place connections, extend as shown on applicable drawing, within specified tolerances.

Inspection of Installation of Inserts and Tendon Ducts

Attributes typically inspected with respect to installation of inserts and tendon ducts are as follows:

- Inserts, such as anchor bolts, bearing plates and lifting devices, located accurately, as shown on the drawings.

- Tendon ducts located as shown on the drawings in a smooth path free from kinks and without interference from reinforcing steel components.
- All embedded items free from deleterious substances that will reduce bond with the concrete, such as form release agents or other contaminants.

Inspection of Installation of Tendons in Pre-tensioned Members

Attributes typically inspected with respect to installation of tendons in pretensioned members are as follows:

- Strands carefully threaded through bulkheads or cages of reinforcing steel to preclude damage from kinks or entanglement.
- Cutting of strand between the vise and the reel, and the nicked segment discarded. (Note: Strand vises, which are used to grip and pull the strands into position, notch or nick the wires at the grip points.)

Inspection of Anchoring and Pre-tensioning of Tendons

Attributes typically inspected with respect to anchoring and pre-tensioning of tendons are as follows:

- Anchorage devices exhibit proper alignment and attachment to the strand, prior to the application of stress.
- Uniform initial tensioning force applied to each strand to result in a final, uniform stress condition in all strands.
- Initial load applied with either pressure jacks or fence stretchers and measured during application. The usual tolerance for initial load is ±50 lbs. or 2%, whichever is larger, but this allowance may vary, depending on the particular job specification.

- Initial load held momentarily while reference marks are applied to the strands for measuring elongation and slippage. The inspector should observe the application of these marks.
- Application and measurement of the final tension force using calibrated gages or dynamometer. Elongation of the strand is measured and recorded, using the reference marks and taken to the nearest 1/4 inch.

Inspection of Concreting Operations

Attributes typically inspected with respect to concreting operations are as follows:

- Batching, mixing, transportation and discharge of the concrete into the forms comply with specification.
- Each batch of concrete delivered to the forms placed as nearly as possible, in final position, adjacent to the preceding and following batch and the whole mass consolidated by vibration with as little lateral shifting as possible.
- Vibration performed to produce a uniformly dense and plastic mass, with the following considerations:
  - Vibrators used for compaction only, and not for moving concrete horizontally along the forms.
  - Spacing of points of vibration such that zones influence overlap for both horizontal and vertical operation of vibrators.
  - For concrete deposited in layers, vibrator inserted vertically and allowed to sink due to its own weight to the bottom of the layer and slowly withdrawn. For succeeding layers, vibrator penetrates the surface of the preceeding layers.
  - Concrete testing operations including sampling, cylinder preparation, slump tests, air content

tests, and compressive strength tests, comply with specifications.

Inspection of Concrete Curing and Form Removal

Attributes typically inspected with respect to concrete curing and form removal are as follows:

- Concrete curing procedures started immediately following the initial set or completion of surface finishing.
- Concrete kept moist to prevent surface cracks due to rapid loss of water from evaporation. (Moisture may be retained by sprinkling or ponding with water, using moisture-retaining covers, or by a liquid seal-coat of a thin water-impervious membrane.)
- Test cylinders of concrete cured, as nearly as possible, in the same manner as the member or structure which the sample represents.
- Forms loosened and removed carefully to preclude damage to the concrete surface.
- For pre-tensioned members, forms loosened or removed before de-tensioning takes place.

Inspection of De-tensioning/Stress Transfer of Pre-tensioned Tendons

Attributes typically inspected with respect to de-tensioning or stress transfer of pre-tensioned tendons are as follows:

- Stress transfer to pretensioned members effected only after specified concrete transfer strength has been attained, as indicated by compressive strength cylinder test results. (Normally, minimum concrete transfer strength is 3,000 psi for typical wet-mix concrete applications.)

- De-tensioning proceeds by gradually releasing the tensioning pressure on the strands, maintaining symmetrical forces about the vertical axis, and minimizing sudden or shock load on the concrete member.
- Multiple strand de-tensioning performed by releasing the strands simultaneously and gradually, by hydraulic jacking.
- Single strand detensioning performed by heat cutting the strands with a low-oxygen flame or other specified method.

Inspection of Installation and Post-tensioning of Tendons in Ducts

Attributes typically inspected with respect to installation and post-tensioning of tendons in ducts are as follows:

- Tendons are pulled through the ducts and anchored at both ends. Anchorages check to verify proper alignment and secure condition.
- Tensioning begins after the concrete has attained the required transfer strength, as determined by compressive strength test results.
- Tendons tensioned in accordance with a specified sequence as determined by the design in order to keep stresses with predetermined limits of symmetry about the axes of the member or structure.
- An initial load applied to each tendon, reference marks applied, and the full load applied. Stress measurements taken by both elongation and gage readings, and checked within 5% of theoretical values.

Inspection of Grouting Operations

Attributes typically inspected with respect to grouting operations are as follows:

- Ducts satisfactorily clean before the grouting operation begins. (Following post-tensioning, tendon ducts are usually flushed with clean water to remove any tendon-lubrication materials or other foreign matter, and blown free from water with clean, compressed air.)
- Grout mixture batched accurately and mixed according to the designated design mix.
- Grouting Techniques including grout pumped into the ducts, toward open vents, under moderate pressure until all entrapped air is forced out the open vent or vents. A steady stream of grout from the vents indicates that the entire duct is filled. At that point, the discharge vents closed, the pressure raised to a minimum of 50 psi and held for a minimum of one minute, after which the injection point is plugged to prevent any loss of grout from the pressurized duct.

EXERCISES

1. State the purpose of items associated with prestressed concrete by completing the Purpose column of Table 29-6-2.

Table 29-6-2

Items Associated with Prestressed Concrete

Item	Purpose
endon	
earing plate	
tendon duct	
grout	
form	
vibrator	
water soaked mat	
hydraulic jack	
load cell	
material test report	
compression test sample	

2. Describe tensioning and de-tensioning of a pre-tensioned concrete member by completing the Description column of Table 29-6-3.

Table 29-6-3

Pre-Tensioned Concrete Member

Operational Step	Description of Step
Form Setting	
Tendon Installation	
Pre-tensioning of Tendons	
Concreting	
Curing and Form Removal	
De-Tensioning	

3. Describe tensioning and de-tensioning of a post-tensioned concrete member by completing the Description column of Table 29-6-4.

Table 29-6-4
Post-Tensioned Concrete Member

Operational Step	Description of Step
Form Setting	
Tendon Duct Setting	
Concreting	
Curing and Form Removal	
Tendon Installation	
Post-Tensioning	
Grouting	

4. A section of a post-tensioned prestressed concrete wall is to be constructed. The drawings of the wall indicate that the wall is reinforced with deformed steel bars and has embedded steel tubes for tendon ducts. Prepare an inspection check-list to cover all construction operations from the setting through final grouting. Submit the inspection check list to the instructor.

MATERIALS

None.

PROCEDURES

1. Tour concrete precasting plant and observe pre-tensioning operations.
2. Tour construction site and observe pre-tensioning or post-tensioning of prestressed concrete members.

DATA TABLE

None.

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TEST

1. State the purpose of concrete prestressing.

2. Name three basic methods for prestressing concrete members and briefly describe how each is accomplished.
   a.

   b.

   c.

3. Describe the role of standards in ensuring quality concrete materials.

4. Name three types of steel tendons used in prestressed concrete applications.

5. State the purpose of tendon ducts.

6. Describe how pre-tensioning of a concrete member is accomplished beginning with forms in place and ending with de-tensioning; include type of tendon, tendon installation, method of tensioning, use of reference marks, and release of tension.

7. Describe how post-tensioning of a concrete member is accomplished beginning with forms in place and ending

with de-tensioning; include type of tendon, tendon installation, method of tensioning, use of reference marks, and release of tension.

8. Briefly describe inspection of the following operations and give two inspection attributes for each.
   a. setting of forms

   b. concreting operation

   c. grouting operations

   d. tensioning of tendons

NUCLEAR TECHNOLOGY

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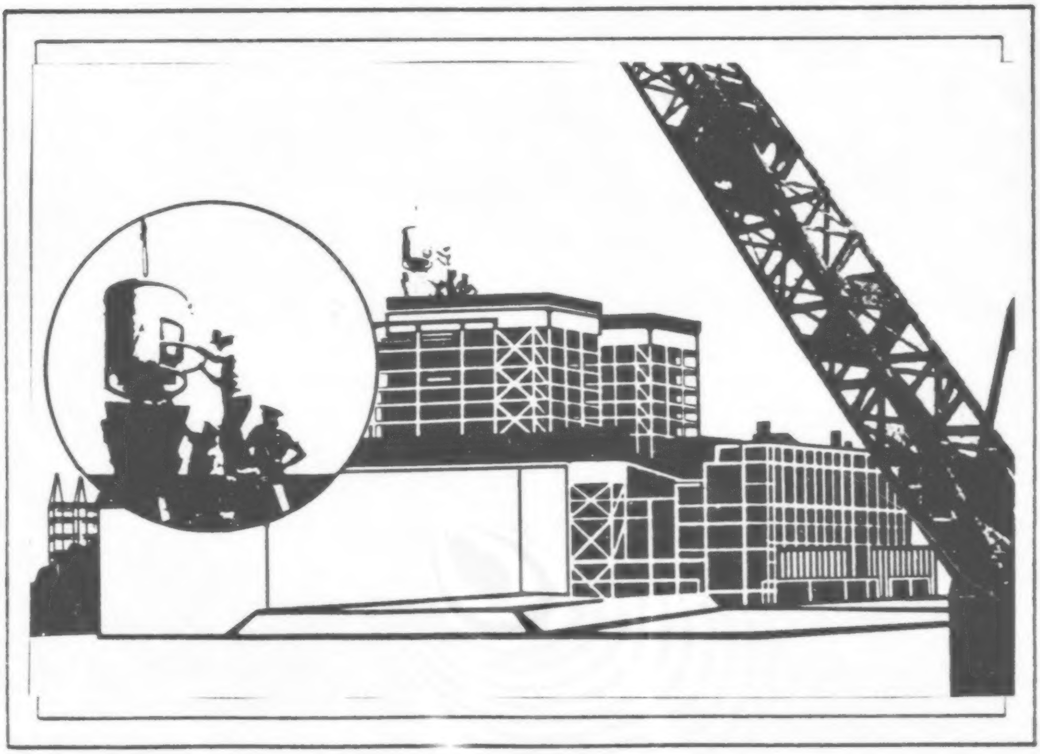

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NUCLEAR TECHNOLOGY SERIES
INDEX
for
COURSE 29, CIVIL/STRUCTURAL INSPECTION (SIX MODULES)

NOTE: Each module in this Course is numbered separately, and the page numbers begin with page 1 in each module. Therefore, this Index lists for each entry the module number (underlined), followed by a comma and the page number. Figures and tables are listed by their numbers, followed by the module and page number in parentheses. A Master Index is available in a separate volume. This general index merges all index entries from the 35 Nuclear Courses. It is a valuable research tool, with which the student or researcher can locate all the references to any subject within the 35 Courses

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